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A DWARF MUTANT IN MAIZE

The dwarf mutation illustrated above appeared in a plot of "Stowell's Evergreen" sweet corn grown at the Connecticut experiment station, New Haven, in 1908, and is described in that station's bulletin No. 167, p. 130. "It was very short (18 inches) and had short leaves of the normal breadth. The joints were very close together, and the whole appearance of the plant suggested a normal plant that had been pushed together like a telescope." Its height is shown by contrast with a single ordinary ear from a normal strain of this same variety, at the right. An attempt to self-fertilize the dwarf failed, so it was cross-pollinated from normal Stowell's Evergreen, and produced one fairly good ear, which was planted. One dwarf like the maternal parent appeared out of 37 plants. From a Mendelian viewpoint it might have been expected that there would be no dwarfs in this generation, but that the normal condition would be dominant. The one dwarf was completely sterile, but a selfed normal plant from the same lot gave two dwarfs out of 76 plants in 1910. E. M. East writes, "I suppose that it is an example of variable dominance such as is often found when one crosses an abnormality with a somewhat mixed population. As every race of corn is more or less mixed, I think it not unlikely that many of these abnormalities should vary all the way from the dominant to the recessive condition in the first hybrid generation of the cross. It is not a peculiar result, but is apt to confuse a person in an open pollinated crop like corn." (Frontispiece.)

ON THE NATURE OF MUTATIONS

Their Cause to be Sought in a Chemical Rather Than Morphological Change in Some Chromosome—New Material Furnished for Evolution—Data from the Evening Primroses.[1]

DR. R. RUGGLES GATES, *University of London.*

EVER since the beginning of the twentieth century, when the principles of Mendel were rediscovered and DeVries published his mutation theory, the nature of the changes which give rise to mutations and to Mendelian differences has been much discussed. For it is obvious that our views on these questions will determine our attitude toward evolution in so far as it is concerned with discontinuity in variation. Mendelian investigators have for the most part assumed that the main point to be discovered is the manner of inheritance of the Mendelian differences found in plants and animals, and have failed to observe that the *origin* of these differences is a wholly different question, requiring in many cases other methods of attack.

It has also been tacitly or speculatively assumed that mutations were in some obscure and hypothetical way the expression merely of new combinations of Mendelian units. This view, or rather group of views (for each Mendelian writer has attempted a different hypothesis, such as reduplication of gametes, coupling of characters, multiple factors, loss of inhibitors, etc.), has only recently been exploded. But it is worth while pointing out that even if this were not the case it would still be necessary to account for the origin of the supposed Mendelian differences. This Mendelian writers have attempted to do by means of the presence-absence hypothesis. But it will be shown later that the latter hypothesis has had placed upon it a far greater weight of speculation than it is able to bear.

The activities of recent years in the study of mutations have, on the contrary, accumulated a mass of positive observations concerning the real nature of mutational changes. These investigations have combined cell studies with observations of the external characters of mutants and their hereditary behavior, both in self-fertilized offspring and in crosses with their parent forms. In this way much light has been thrown upon the nature of mutation as a process of variability. It has been definitely shown that mutation is a type of variation and cannot be explained in terms merely of heredity, Mendelian or otherwise. The cell studies of mutants in particular have been crucial in eliminating the various Mendelian hypotheses of mutation, for the latter are found to be directly contrary to the cytological facts. These facts have also made it possible to construct a new theory of mutations in general which helps to illuminate the whole subject and harmonize the Mendelian and mutationist views.

We are thus led to adopt a new attitude toward the subject of heredity as well as that of variation; the latter being concerned with the origin of differences between related organisms, while the former is concerned with the perpetuation of those differences after they have originated.

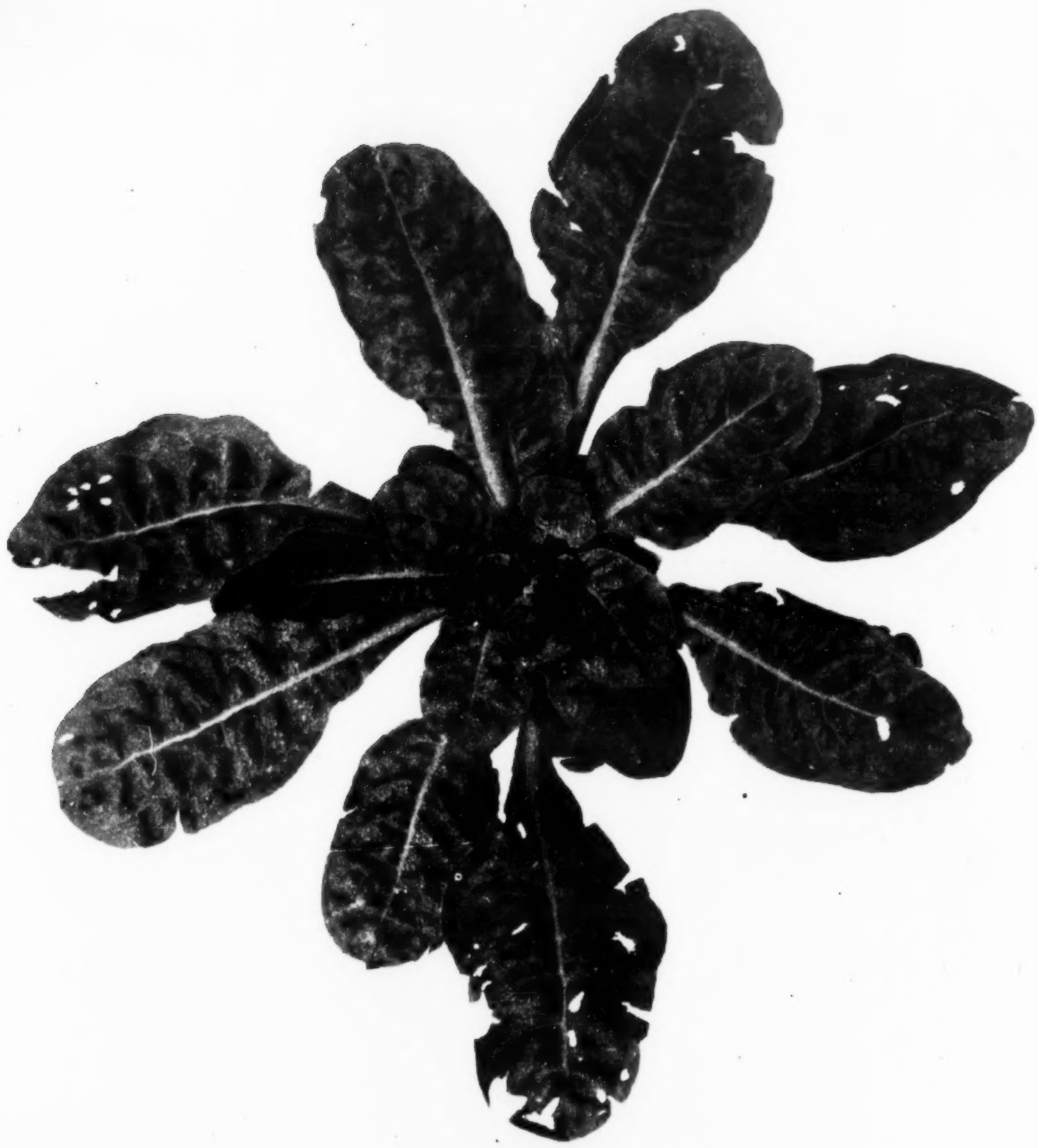
EVIDENCE FROM THE PRIMROSE.

The critical and decisive experiments concerning the nature of mutations have, as is well known, been made in the evening primrose genus Oenothera. Here the numerous attempts to explain the origin of the mutants in terms of the recombination of Mendelian factors have broken down. For a number of years it has been assumed in various

[1] Presented before the Botanical Society of America, Philadelphia, Dec. 30, 1914.

LAMARCK'S EVENING PRIMROSE

This common flower is supposed to be a native of the central eastern portion of the United States, but was early introduced to Europe and is now found wild there in many localities. The Dutch botanist Hugo de Vries found a number of them in a field near Hilversum, Holland, which were undergoing unusual changes in form. He brought them to his garden, propagated them, and found that these changes were continually produced, that some of them were very great, and that most of them bred true. This was the starting point of the Mutation Theory which marks an epoch in the study of evolution. (Fig. 1.)



AN EARLY DISCOVERED MUTANT

Rosette or young seedling of *Oenothera lata*, a mutant from *Oenothera lamarckiana* (shown in fig. 1), which was discovered by De Vries as early as 1887. Even the youngest leaves have broad, rounded tips, in contrast to the more pointed ones of the parent form, and the leaves are also more crinkled. It has been shown that the cells of this plant contain an extra chromosome not present in those of the parent, and it is this, apparently, which determines the nature of this mutant. (Fig. 2.)

quarters that *Oenothera lamarckiana* was a "hybrid," although it has usually not been stated in just what sense this term was used. More recently all Oenotheras have been stigmatized as hybrids, and the conception has even been extended to the whole family of Onagraceae. It seems that this is the fate of all organisms which come to be intensively studied from the genetic point of view.

Having regard to the facts, it is not necessary to suppose that any recognized species of Oenothera is a hybrid in the sense of having been synthesized directly through crossing between two other species. An extraordinary flaw in all the reasoning in this subject has been the tacit assumption that if any plant could be shown to be a "hybrid" then any mutations it might produce must be a result of that condition. But it is necessary to point out that even if the assumption that all Oenotheras are

hybrids were true, it would still be necessary to inquire whether the types of variation found in *Oe. lamarckiana*, *Oe. biennis*, *Oe. grandiflora*, and other species are merely the result of hybrid processes, or whether mutation and hybridization are distinct processes.[2]

MISSHAPEN BUDS

The petals in the bud of *Oenothera lata* are crumpled, causing it to be misshapen; the anthers are sterile or nearly so, and relatively few seeds are produced. The buds are stouter and more barrel-shaped in this mutant than in any of the other forms except *gigas*. These buds are natural size. (Fig. 3.)

The cell studies of the Oenotheras have abundantly proven the latter view. The nature of the explanation of mutations is also very usefully limited as well as illuminated by the cytological results. Mutations of course occur in hybrids as well as in pure strains, and it is usually possible without much difficulty to pick out the mutants in heterogeneous F_2 hybrid families. Confirmation of many such cases can afterward be made by cytological study, and others can be analyzed by breeding from them.

As illustrations of the new point of view with regard to mutations we may select three of the mutants of Oenothera. A flowering shoot of *Oe. lamarckiana* is shown in fig. 1. The mutants, *lata*, *gigas*, *rubricalyx* are all derived from this species, the last, however, being a secondary mutation, which originated directly from *rubrinervis*, itself a mutant from *Oe. lamarckiana*.

OENOTHERA LATA.

In this mutant and certain others, duplication of a chromosome has taken place, and the writer showed some years ago[3] that this happens through one chromosome of a pair passing into the wrong nucleus in the reduction division. It is now known[4] that *lata* has constantly 15 chromosomes instead of 14 in the nuclei of all its cells. Fig. 2 shows a rosette of *lata* with its deeply crinkled and peculiarly obtuse leaves. This mutant also has a peculiar habit of growth, and its buds are misshapen (fig. 3), the anthers being almost completely sterile. Various other features characterize this very interesting form which was first discovered by De Vries as early as 1887.

Not only is the extra chromosome constantly associated with these peculiarities of *lata*, but its presence determines the inheritance of *lata*, for its offspring consist chiefly of *lata* (with 15 chromosomes) and *lamarckiana* (with 14 chromosomes) in varying proportions. *Oe. lata* appears in different races and species (including *Oe. biennis*) when this irregular meiotic division occurs. The peculiarities of *lata* thus arise from the fact that its nuclei contain 15 instead of 14 chromosomes. This condition arises in the fertilized egg and is passed on to every cell of the plant by the mitotic mechanism.

[2] See Gates, Breeding experiments which show that hybridization and mutation are independent phenomena. Zeitschr. f. Abst. u. Vererbungslehre 11: 209–279. Figs. 25.

[3] A study of reduction in *Oenothera rubrinervis*. Bot. Gazette, 46:1–34. Pls. 1–3.

[4] See Gates and Thomas. A Cytological study of *Oenothera* mut. *lata* and *Oe.* mut. *semilata* in relation to mutation. Quart. Journ. Micro. Sci. 59:523–571, pls. 35–37, figs. 4.

THE GIANT PRIMROSE

Rosette of *Oenothera gigas*, another mutant from Lamarck's species. The leaves are larger and thicker and with rather blunt tips. With the exception of a few features, this sport breeds entirely true. Reduced in size in reproduction. (Fig. 4.)

The mutation is therefore a nuclear change, which is represented in every cell of the organism, and it will be found that the same is true of every mutation, at least in plants. They are germinal changes of such nature as to be represented in every cell, having been propagated by mitosis from the fertilized egg.

OENOTHERA GIGAS.

This mutant represents another kind of germinal change—tetraploidy. A rosette of *gigas* is shown in fig. 4 and full grown plants in fig. 5. The plant is larger and stouter in nearly all its parts, except in height. There are various other modifications from *Oe. lamarckiana*, as in the shape of the leaves, and a striking feature is the presence of four-lobed instead of three-lobed pollen grains—a condition not known to occur in any other evening primrose. Many of these peculiarities, though perhaps not all, result from the tetraploid condition,—the nuclei contain 28 instead of 14 chromosomes and as a result the nuclei and cells in all tissues of the plant are conspicuously larger.[5]

The doubling in the chromosome number, however it has taken place, is a distinct process from the irregular chromosome-distribution which gives rise to the *lata* type of mutation, for in this case the whole chromosome series has been doubled. Tetraploidy is now known in a long list of plant and animal species, which must have originated suddenly from a related species, in the same manner that *Oe. gigas* appeared. Here again the change is a cell change, propagated by mitosis to every part of the organism.

[5] Gates, R. R. The stature and chromosomes of *Oenothera gigas* De Vries. Arch. f. Zellforschung 3: 525–552, 1909.

ADULT PLANTS OF THE GIANT MUTANT

Its difference in habit from *Oenothera lamarckiana*, the parent form, may be seen by comparison with fig. 1. There are usually few side branches, the internodes are short, and the large, deeply crinkled leaves tend to hang downward on the stem. The flowers are larger and the buds stouter than in the parent form. It has been found that the cells of this mutant contain twice as many chromosomes as those of the parent, a fact which perhaps accounts for the increased size and vigor of this sport. From a photograph kindly loaned by Dr. B. M. Davis. (Fig. 5.)

A DIFFERENT TYPE OF MUTANT

Oenothera rubricalyx originated in the breeding-plot of Dr. Gates in 1907 and is quite unlike all the other primrose mutants. It did not spring directly from Lamarck's primrose, but from a mutant of it, *Oe. rubrinervis*. In the mutant here shown the under sides of the leaves, and the flower stalks, are red, whereas in the parent they are green. Dr. Gates assumes that some chromosome in the reproductive cells has undergone a chemical change, which leads to an increased production of red pigment, and thus to the mutation. (Fig. 6.)

Another interesting fact concerning *gigas* is that its inheritance is entirely different from that of *lata*, since *gigas* breeds true except for remarkable variation chiefly in foliage. This variability is probably concerned with new combinations of the double chromosome series. In crosses also *gigas* behaves differently from *lata*, giving intermediate hybrids which essentially breed true. This difference in behavior of *gigas* and *lata* is undoubtedly concerned with the different chromosome content of the two forms, and is explainable in terms of those differences.

If now we consider *rubricalyx*, we find the type of change entirely diverse from either of those mentioned above.

THE RED MUTANT, FULL GROWN

Adult plant of *Oenothera rubricalyx*, a young seedling of which was shown in the preceding illustration. The number of chromosomes in its cells is 14, as in those of its parent; Dr. Gates therefore argues that the origin of the mutation must be chemical in nature, and not morphological. (Fig. 7.)

This mutant originated from *rubrinervis* in my experiments in 1907, as a dominant heterozygous mutation, its offspring giving *rubricalyx* and *rubrinervis* in a 3:1 ratio.[6] It is a striking color variety of *rubrinervis*, the two being morphologically identical. A rosette of rubricalyx is shown in fig. 6 and a full grown plant in fig. 7. In *Oe. rubricalyx* the under side of the leaf petioles of the rosette as well as of the flower stalks or hypanthia, are red, whereas in *rubrinervis* they are invariably green.[7]

In *rubricalyx* there is also greater production of red pigment in every part of the plant, as may be observed by examining sections of the fresh tissues under the microscope. The capacity of the cells for producing anthocyanin has suddenly undergone an enormous increase.

Any theory which will explain the origin of *Oe. rubricalyx* will explain also the origin of all Mendelian differences, for this is inherited in simple Mendelian fashion, wholly unlike either *lata* or *gigas*.

If we assume that one member of one pair of chromosomes has undergone a chemical change to lead to the greatly increased pigment production, then we can explain at the same time the origin and inheritance of this mutant. We therefore conclude in general that simple Mendelian characters arise through an alteration on the part of a chromosome, analogous to the mutations which are known to occur in certain bacteria.

This type of change is of course entirely different from those already mentioned, and is sufficient to account for the origin of all mutants which are inherited in Mendelian fashion. The change is fundamentally chemical rather than morphological in nature, the chromosomes in *Oe. rubricalyx* numbering 14, as in *Oe. lamarckiana* and *Oe. rubrinervis*.

From such facts as these the following conclusions regarding the nature of mutations may be drawn. (1) Mutations are of many kinds and in many directions. (2) Evolution is not due, as Bateson[8] and others have urged, to the loss of factors or inhibitors from the germ plasm, but mutations furnish abundant material for real evolution, in which the modification of characters, and divergences in many directions, have occurred. There is really no more reason for supposing evolution to have resulted from "loss of inhibitors" from the germ plasm than there is for the embryologist to assume that the egg develops into a chick by throwing off inhibitors during ontogeny. This type of embryological speculation was supplanted centuries ago by the observed increase in complexity and structure during development of the individual.

The evolutionary conception of loss of factors and inhibitors has been founded upon the Mendelian presence-absence hypothesis. The usefulness of this symbolism in the study of the inheritance of Mendelian characters cannot be gainsaid. But as soon as it is applied to evolutionary conceptions it leads to an erroneous point of view. It is safe to conclude that even apparent losses, such as the origin of recessive white varieties from colored varieties of plants and animals, are not really due to the loss of any particle from the germ plasm, but to a chemical (probably in some cases stereochemical) modification in one element of the germ plasm, viz: a chromosome or a portion of one.

(3) Finally, another generalization should now be seen to follow clearly from such facts as those mentioned in this paper, namely, that the inheritance of any character depends to some extent upon the nature of the character. In other words, the manner of inheritance of any character is determined, or

[6] Shull (A peculiar negative correlation in *Oenothera* hybrids. *Journ. Genetics* 4: 83–102, pls. 5–6, 1914) has erroneously attempted to show that *Oe. rubricalyx* is not a simple Mendelian dominant. The plants in his experiments which he treats as pure *rubricalyx* are obviously, from his own figures, hybrids with a distinct species *Oe. grandiflora*, and the supposed discrepant results he obtains are in fact, as far as they go, a confirmation of the writer's extensive crosses of these two forms.

[7] The history of the origin of this mutant is given in "Studies on the variability and heritability of pigmentation in Oenothera." Zeitschr. f. Abst. u. Vererbungslehre 4: 337–372. Figs. 5. 1 colored plate, 1911.

[8] Problems of Genetics. London, 1913.

at any rate limited, by the manner of its origin, *i. e.*, by the nature of the germinal change by which it appeared. Just as there are different types of discontinuity in variation, so there are various methods of inheritance of the differences which thus arise. These methods of inheritance naturally depend upon the basic nature of the original change.

ANNUAL MEETING OF THE ASSOCIATION

THE annual business meeting of members of the American Genetic Association was held in the Cosmos Club, Washington, D. C., at five o'clock on the afternoon of Thursday, January 14, 1915, as provided by the by-laws.

The three retiring members of the council were re-elected by the following motion, carried by a unanimous vote: "Resolved, that the secretary be instructed to cast the unanimous ballot of this meeting for Alexander Graham Bell, W. E. Castle and Bleecker Van Wagenen to succeed themselves as members of the council of this association; and that this action is not to be considered a precedent, but is considered fair because the three retiring members have served one year only, and not the normal term of three years."

The meeting approved the plans of the council to hold the annual convention of the association at Berkeley, California, August 2–7, in connection with the meeting of the American Association for the Advancement of Science.

At the annual meeting of the council, held at the Cosmos Club at 5 o'clock on the afternoon of Tuesday, January 19, in accordance with the by-laws, the present officers of the association were all re-elected, and Thomas H. Kearney was elected a member of the executive committee for the ensuing year, the other two members being the president and secretary, *ex officio*.

Conditions of Mendelian Inheritance

If we take "Mendelian inheritance" to signify the mode of inheritance Mendel found to prevail in his researches on seven differentiating characters in peas (except that perfect dominance need not be present), the following are some of the complications which must be absent in order that *simple* Mendelian inheritance may appear.

1. Each single factor must pass indifferently into half of the pollen-grains and half of the embryo-sacs. There must be no such *multiplication* of factors as occurs in the origin of some giant Primulas and Œnotheras.
2. There must be no such coupling or repulsion between the factors as has been found in sweet peas, primulas, snapdragons, peas, and velvet beans.
3. There is usually some elimination of pollen-grains and embryo-sacs; but there must be no elimination that has any relation to any of the factors in question, such as occurs in certain Stizolobium hybrids, and doubtless in Œnotheras.
4. There must be no inherited difference in the fertilizing power of different "good" pollen-grains from the same anther. If a definite fraction of the pollen-grains fail to fertilize the ovules (as Correns found in Mirabilis), then a selective *partial* self-sterility, or *partial* incompatibility occurs, which may complicate the results.
5. The death of certain embryos within the ovules or young seeds (which seems to occur in most plants), must not be due to any *inherited* weakness of these particular embryos.
6. There must be no such differential viability of the seeds as has been found in double stocks by Saunders, and in *Œnothera lamarckiana* by DeVries.
7. If a definite fraction of the young seedlings perish unnoted, this will make abnormal ratios, as occurred in Baur's first experiments with the golden-leaved snapdragon.
8. Plants which die before maturity must not do so from inherited weakness, or the final ratios may not be typical.

Mendel's law is only the alphabet of the subject of heredity. The simple law of gravitation is also easy to grasp, but much work of many astronomers was required to fit this law to the actual motions of even one planet. I think that heredity may be found, in the end, to be nearly as complicated as astronomy.

JOHN BELLING, *Florida Agricultural Experimental Station.*

GERMAN ZOÖTECHNY

Immense Strides Made by Live-Stock Industry of the Empire are Largely Due to Science of Genetics—The Importance of the Pedigree—Line-Breeding.

Review of a book by GEORG WILSDORF

Tierzuchtdirektor und Hauptgeschäftsführer der Deutschen Gesellschaft für Züchtungskunde, Berlin, Germany.

GERMANY'S large contributions to the science of genetics during the last half century are well known, but the extent to which they have been put to practical use by the Germans themselves is much less familiar to Americans. Some of the brilliant work in plant breeding is indeed recognized; but it is probable that few members of this association have any clear idea of the present state of the science of animal breeding in the German empire. It may be of interest, therefore, to review at some length a brief but authoritative statement of the situation from the pen of Dr. Georg Wilsdorf, general director of the influential German Genetic Association.

Dr. Wilsdorf's little book on Animal Breeding[1] was first published in 1912 as one of a series of popular hand-books on scientific subjects. In 1914 it was reissued as a bulletin of the German Genetic Association; it seems reasonable to assume, therefore, that its doctrines are those accepted by the leading zoötechnists of Germany.

The live-stock industry of Germany (reaching its highest development in the northwest) has increased until it now surpasses the agricultural and horticultural industries in importance, according to Dr. Wilsdorf, who estimates the yearly production of animal husbandry at $1,675,000,000 as against $1,300,000,000 for the produce of field and garden. And while he recognizes that this gradual preponderance of livestock over the agricultural industries has been largely due to economic conditions, he thinks it has only been made possible through an intelligent application of the principles of genetics. The demands made by the farmers on science have, he says, changed the whole character of zoölogy in Germany; while the zoölogists formerly concerned themselves almost exclusively with wild animals, the tendency now is rather to concentrate attention on the domesticated ones.

A CHANGED VIEWPOINT.

But the studies of zoölogists and the experiments of naturalists on zoötechny can easily be credited with more influence on the live-stock industry than they really have had; for, as the author points out, the fundamental fact in the successful application of genetics to animal breeding is not the discovery of any new law, but a change in the viewpoint of breeders. In the past, they have looked only at the generation or two before their eyes; the acquirement of a habit of looking as far back as possible, instead of merely at the animals immediately to be mated, is what has revolutionized animal breeding. In other words, it is the realization of the importance of the pedigree that has made animal breeding a science rather than an art. Such a statement might justly be considered the text of Dr. Wilsdorf's book, for to it he returns time after time.

The importance of pedigree above everything else was realized by the Arabs centuries ago, but is still ignored by many a breeder in Europe and

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[1] "Tierzüchtung" von Dr. Georg Wilsdorf, pp. 110, figs. 23, price one mark, bound in linen M. 1.25; Bändchen No. 369 "Aus Natur und Geisteswelt" sammlung, B. G. Teubner, Leipzig, 1912; 17th Flugschrift der Deutschen Gesellschaft für Züchtungskunde, Berlin, 1914.

America. It is being emphasized on both continents, however, by the development of breeders' association and herd and stud books, with the subsequent premium put on accurate registration. In Germany the development of these instruments has proceeded on much the same lines as in America, but there has been more coöperation between the promoters of different breeds —a coöperation largely brought about by the huge and powerful German Agricultural Society, whose 18,000 members represent the advanced element in scientific agriculture in the empire; and largely directed by the German Genetic Association, whose principal function is the registration of pedigrees and their subsequent study. It is chiefly as a result of the work of the latter, Dr. Wilsdorf says, that sentiment in Germany has been changed on the subject of line-breeding. The verdict of the older school of zoölogists had been against it, but impartial examination of horse pedigree charts by Lehndorff and others convinced them that much of the progress made in the live-stock industry was due to line-breeding, and they began to recommend it. Then the value of a "genetic analysis" of each animal came to be realized—that is, an examination of its ancestry to determine how it should be mated. A good example of the way pedigree study can be put to use is his description of the work of the famous zoötechnist Dr. de Chapeaurouge at the national stud farm in Celle. He brought together pedigrees of many of the Hanoverian stallions there and found that the stallion Nording got good colts in some districts, but very poor ones in others. This fact had been recognized by the Celle breeders, but its cause was a complete mystery. Testing theory by fact, de Chapeaurouge was able to prove that the good colts were regularly produced when Nording was mated to a mare with which he was related. As the mares in his own particular district were much more likely to be related to him than were mares of more remote districts, the result was that he had been getting valuable colts in that district and comparatively worthless ones whenever he went out of it—a result that would have remained a mystery, had it not been demonstrated that the principle of consanguineous breeding was sufficient to explain it.

CONSANGUINITY WIDESPREAD.

The amount of consanguinity among the domesticated animals of any district is, as Dr. Wilsdorf points out, easily under-estimated. "Suppose we take, as illustration, a valley in which there are 50,000 head of stock of any given kind. If this number of animals had only parents, grandparents and great-grandparents which were unrelated to each other, then we would have—reckoning 14 ancestors for each animal—700,000 unrelated animals as ancestors of these 50,000. If one tries to find out whether such a condition could actually exist in practice, and examines the pedigree book of some large herd, he finds the actual number of ancestors is immensely smaller than calculation led him to expect. The same animal will appear over and over again in the ancestry of a given individual, so that most of the animals now living trace back to numerous common ancestors. In the herd which we have taken as an illustration, we would not find 700,000 ancestors, but perhaps half that many, or even less.

"In our studies of the history of various breeds, we next made the astonishing discovery that the best living individuals belonged to families which, when their pedigrees were traced, were found all to come from a single family—often from a single individual. By way of illustration I might cite the Hanoverian halfbloods, which we know particularly through the studies of de Chapeaurouge and Grabensee to have come almost altogether from three stallions, of which Norfolk has hitherto had the greatest influence on the breed—an influence that is increasing all the time. Researches into the swine breeding of the Visselhövede district, and into that of Hildesheim in Bavaria, have shown that in each case a single boar was the ancestor of various valuable families, today widely scattered. And Hoesch of Neukirchen has found that his valu-

able strain of swine is principally due to the blood of a single early boar Richard."

This means that the origin of most of the valuable strains of live-stock in Germany has been due to line-breeding —and the same is true of any other part of the world. The value of such breeding was known to the Greeks and Romans, but after their time it fell into great disrepute, partly from theological reasons, and until recently, the author says, it was considered not only a questionable, but a distinctly dangerous procedure in Germany, while even today many a breeder will pay a higher price for an animal if he feels sure that it is not related to any now in his herd. "The modern science of breeding, however, stands firm in its belief that for the production of definite types for special purposes in-breeding is the quickest and most certain method of procedure, and all great breeders who work toward any particular goal depend largely on in-breeding, knowingly or unknowingly."

REVERSION OR ATAVISM.

A certain amount of inbreeding is undoubtedly necessary to preserve the type of any purebred strain of stock; conversely, the quickest way to break up the type is to mate with some widely differing animal. Even if the mating be between animals which look exactly alike in respect to any given character, that character will frequently disappear altogether in the offspring and be replaced by some character presumably belonging to the breed or species very early in its history: this is the phenomenon of atavism, reversion or "throwing back." It is particularly common in our domestic animals because, as Dr. Wilsdorf points out, most of them seem to be the product of the union of several different races or even species, at some remote time in the past. The result of such mixture is seen in an interesting case he cites, of the herd of white cattle owned by the King of Württemberg and kept in Rosenstein Park near Stuttgart. "Here a pure white herd has been bred for many years, and new pure white males of many breeds (Schwyzer, Allgauer, Simmentaler, Limpurger, Swabian Haller, Hollander, East Friesian, Shorthorn, Alderney and Zebu) introduced at intervals. But although no animal which was not white has been introduced, so far as is known, since the herd was established, a number of calves are born each year which are not white, but some other color."

Most existing breeds of live stock probably have an origin not very much less mixed than that of the King of Württemberg's white cattle: the mixture was made at a more remote period, however, and its complexity is therefore not so vividly realized.

With material of that sort to work on, it is evident that the task of the modern breeder is one of great delicacy. His chief object is to produce animals that are all of one type; and yet the very make-up of his stock makes it inevitable that nature will constantly strive to break away from that artifical type and return to the more primitive characteristics. How shall the breeder thwart this effort of nature?

As suggested above, he does it by line-breeding, that is, by breeding in one blood-line as much as possible—"pure breeding." The so-called "purebred" animal, then, has been produced by line-breeding more than by any other factor.

"Strictly speaking, any introduction of foreign blood would result in the breed no longer being 'pure.' But frequently it is to the interest of the breed to introduce a new blood stream, that is, new and valuable characteristics. Speaking by and large, one cannot then say that the breed is no longer pure; the word 'purebred' is relative, not absolute, in its meaning. Our producers of purebred stock frequently speak of 'crossing' when they employ stock for breeding which is not quite their ideal in type. Here again the idea of 'purebred' is pretty narrowly construed. The practical breeder understands it more broadly: for him the mating of animals of the same type is pure breeding."

To sum up, the triumph of scientific animal breeding has consisted in the suppression of natural diversity and in breeding animals true to a fixed type: the study of pedigrees and the utiliza-

tion of the information they gave by means of line-breeding have been the chief instruments of the scientific breeder.

FIXING THE STANDARDS.

It will be obvious from this that nothing is more important than to have a satisfactory fixed type. If our standard is wrong, then increase in skill in breeding, improvement of the technique, is of little value. The genetist's ability to use the laws of heredity will be of little avail, unless the standard toward which he is breeding is as good as science can define. Dr. Wilsdorf therefore emphasizes the great advance that has been made in this direction in Germany as in most other parts of the world during recent decades. It was not long ago, he points out, that breeding was merely a matter of mating two animals, without much regard either to their pedigrees or to their performances. Now it is recognized that these two factors must go together, each supplementing and interpreting the other; and the development of performance tests has therefore become a part of the breeder's work not only important but absolutely necessary. In horse breeding, the race track justifies itself largely on this ground; horse shows do, too, when the practical element is not wholly submerged by the sporting element; while endurance tests and work tests for the heavier horses are now being developed, particularly at the national stock farm of Warendorf, where the annual "Warendorf Week" draws draft animals from many regions, to be submitted to tests of hauling cars loaded with sand, that will give any competent judge a good idea of what kind of a constitution they have inherited and are likely to pass on to their offspring.

Cattle breeders took up the idea of performance tests far later than horsemen did, for in earlier times cattle were largely valued as draft animals, and milk production was an insignificant side issue. During the last century, however, the development of the milking function, through conscious or unconscious performance tests and selection of the best producers for breeding, gave marvelous results. The average yield of German cows at different periods is stated by the author in the following table:

1790.....	¾ quart
1800.....	1½ quart
1810.....	2 quarts
1820.....	3 quarts
1830.....	4 quarts

This quantity was maintained for three decades. Then, with the collapse of sheep breeding in Germany, dairy cattle again received an unusual amount of attention, with the result that the figures were increased to:

1860.....	6 quarts
1870.....	8 quarts

From this point on, the physiological limit began to appear in sight, and the increase was necessarily slower. But the nearer the physiological limit came, the more careful were breeders to test and select only the finest milk-yielding strains, with the result that at the beginning of the twentieth century, Dr. Wilsdorf thinks the average daily milk production of German cows may be placed at 10 quarts. In one century, their yield was increased more than 1000 per cent. by intelligent breeding—certainly as good an example as one could ask of the practical value of genetics.

FORM VS. REAL VALUE.

Production tests for beef cattle, on the other hand, have helped to make clear to breeders the difference between bodily and germinal qualities. There was a period when the study of type was the prevailing fad, and when it was believed that if you had animals conforming to a certain ideal beef type, you would have ideal animals to breed from as well as to butcher. This gave rise to a number of herds that were very pretty to look at, but caused disillusionment later on, for as the writer tersely says, Handsome is as handsome does:—"The level-headed farmer properly considers an animal beautiful, when its production is beautiful." It was soon found that bad form and considerable departures from the ideal type might be associated with

first-class production-capacity, and this brought home a realization of the fact that the latter quality was a matter of inheritance, and might or might not be identified by the "show form" of the animal in question. Now the practical breeder spends more time studying pedigrees and less in measuring the relative proportions of the parts of his animals; "for if an animal has nothing more to show than a beautifully proportioned body, and is a second-class producer, there is no room for it in practical animal husbandry." After 40 years of careful tests, made possible by the invention of suitable apparatus, the dairyman knows that the family to breed from is the one that yields the best quantity and quality of milk, not the one that produces calves most like the pictures in some "Standard of Perfection."

During all this time an effort was being made to find some connection between form and capacity—to find correlations, as the professional genetist would say, between some features of the body and the milk yield. One after another was advanced; many writers established imaginary "milk types," some of them on the most unbelievable grounds. "It has not yet been proved," in Dr. Wilsdorf's opinion, "that any certain characters or forms give any reliable indication about the milk yield of a cow." He does not hold it impossible that such correlations may eventually be found, but points out that the careful experiment of Gaude with nearly 1,000 cows in East Friesland showed "that the influence of such factors as feed, work, care, pasturage, etc., caused so much change in bodily conditions as to make the probability of recognizing 'milk indications' very unlikely."

Of all civilized countries, Germany has the greatest number of breeds of cattle—probably a hundred, many of the smaller of which are now dying out. But only in two places are the herd books sufficiently full and ancient to make pedigree breeding satisfactory: among the Shorthorn breeders, and in East Friesland where the Holstein-Friesian cattle are bred. In the latter district, the records show that most of the good animals trace back to one of a very small number of good bulls: "Primus," "Matador," "Bernhard," and "Max."

PRACTICAL PEDIGREE STUDY.

"How important pedigree study is may be illustrated by an experience of my own. For 12 years I have been a member of the live-stock purchasing committee of the Brandenburg Board of Trade in East Friesland, and at the very beginning of my activity learned that a promising looking black and white bull in one district of the province of Brandenburg, although bred to excellent cows, got offspring of mediocre value, both in form and in color. Investigation showed that the bull was from a herd of black cattle in East Friesland, which a few years before had been 'graded up' from a herd of brown cattle. This fact, extraordinarily unfortunate for the breeders of the district in which he was located, gave me occasion to begin investigating personally the pedigree of every sire which was thereafter brought into the region, and to require from owners of calves by him periodical reports in the future. I checked up these reports at every sale of East Friesian cattle and in the course of a few years had satisfactory evidence as to the breeding value of practically every important strain of cattle in the region, so that little by little we were able in our yearly purchase to get cattle of greater breeding value into the province. What we did must be done sooner or later by the breeders of every other district: they must find out the actual value of all stock offered them, from a genetic point of view."

While science has been applied to horse and cattle breeding with results highly gratifying to German pride, the sheep breeders seem to have fallen behind. Lack of careful selection, and inbreeding of bad animals rather than good, are blamed in part for the ruin of the industry—among other troubles, it is stated that a failure to select fecund strains led to a decline of fecundity in German sheep

In swine breeding, too, science has made slow progress; but as successful swine breeding is easier than successful sheep breeding, Germany still holds an important place in this field. Most of the swine are in the hands of small breeders, among whom there is a widespread prejudice against line-breeding; this leads to the constant introduction of foreign blood and the result is a failure of the herd to improve, or frequently an absolute deterioration of the strain.

An example of the changes that may be made by systematic breeding is offered by the widespread goat industry of Germany. In the last 20 years the goats of the empire have almost wholly been changed from horned to hornless, by the introduction of hornless Swiss breeding stock. The same cause has led to the disappearance of the old colors and their supplanting by white and brown.

Turning to a consideration of the formal laws of heredity, Dr. Wilsdorf shows himself to be a conservative. He frankly recognizes that most of the knowledge now in the possession of animal breeders on this subject is the result of the research of plant breeders, and he sees no objection to this state of affairs, since it is now pretty generally admitted that, on the whole, the laws of heredity that apply to one section of the living world apply to others as well. He further recognizes that formal laws of genetics as yet can give little real help to the animal breeder.

MUCH YET TO BE LEARNED.

"When the architect builds a house," he writes, "he can say in advance, 'The house will be like this: it will have such and such a height, such and such a shape,' and so on. The gardener who has to lay out a garden or park can tell in advance just how the result of his work will look. He picks out the places where the paths will run, where turf will be planted, where flowers will appear; and he can say to himself, 'In this place such and such a tree will grow.' Architect and gardener alike know beforehand how the finished product of their work will look; but not so the animal breeder. He is dealing with laws of nature which are not yet well enough known to enable him to predict with absolute certainty how they will work. One knows well enough that the offspring of two parents usually is like them, but whether it will more resemble the father or the mother can not with certainty be foretold. Exactly in this uncertainty lies the difficulty of the animal breeder's work. It has therefore long been the aim of experimental breeding and particularly of experiments in hybridization, to find certain rules with which heredity complies. We are well aware that there are animals which transmit their characteristics with unusual prepotency, and we can say with a good deal of certainty that the product of most of these animals will have a large proportion of those characteristics. But frequently enough comes a case where we are deceived, and the number of cases in which we can speak of a 'rule' is proportionately very small: the part of the breeding industry in which we still walk in uncertainty is much larger than that in which we can advance without groping.

"The search for these rules, however, has occupied a great number of naturalists during recent years, and still occupies them. The work hitherto accomplished is a great one and, even if the goal is still a long distance ahead, we have nevertheless taken a big step forward. Plate distinguishes four different methods of heredity, as follows:

1. Mosaic heredity.
2. Blending or intermediate heredity.
3. Mutational heredity.
4. Alternative, segregating or Mendelian heredity.

"In mosaic heredity the characters of the parents exist side by side in the offspring—as in a mosaic. As example I may cite the barred progeny of white and black fowls bred by Davenport; or the color of the well-known Blue Andalusian fowl, where the pigments black and white, intimately mixed, produce an apparent blue color. Hilzheimer cites the Baldinger Tiger Swine as an example of this sort of heredity: it was produced by crossing the white native race with the black Berkshire.

"The second method of heredity is the blending. In it the characters fuse together so that the product stands half way between the two parents. The mulattoes resulting from crosses between negroes and whites may be cited in this connection: their color is constant in succeeding generations.[2]

"In mutational heredity a form appears in the first generation which was not present in either of the parents. As an example genetic literature usually cites Bateson's cross of fowls with rose comb and fowls with pea comb; the offspring had a walnut comb—that is, an entirely new form; which however, could not be bred pure in succeeding generations, but segregated in the second generation, in the following proportions: 9 offspring had a walnut comb, 3 a rose comb, 3 a pea comb and 1 a single comb."

THE VALUE OF MENDELISM.

More important than these to the breeder of live-stock is the fourth method, Mendelism, Dr. Wilsdorf says, but after he has explained it at some length, he feels obliged to conclude:

"Now if we ask ourselves what importance Mendelism has for practical animal breeding, we must admit at the very outset that the development of the rule is still too new to admit of sure conclusions. In this day no one is likely to deny that a thorough knowledge of this rule, which solves so many problems that before its discovery were absolute mysteries, is of the first importance. In agricultural animal breeding, however, we are confronted by one almost insuperable difficulty—that our most important domesticated animals bring only one offspring into the world at a time; whence the conditions of heredity are naturally not easy to observe. It is only with such animals as swine, which produce larger numbers of young at a time, that one can derive much immediate help from Mendel's Rule."

Furthermore, he points out, "it is by no means assured that *all* characters Mendelize." On the whole, he considers Mendelism an instrument of great future promise, but one which is hardly likely to be of much value to the practical breeder at the present day.

Telegony and maternal impressions are mentioned as supposed factors to which many breeders ascribe unexpected variation. As Dr. Wilsdorf says, these can no longer be considered anything but superstitions, yet they are still widely held. "In East Friesland, the Eldorado of the German cattle industry, many breeders still believe heart and soul in the power of maternal impressions on the cow. If a red or red-and-white calf is born in a herd of solid black-and-white color, the mother must have looked at some red object. You can argue as much as you like, this explanation can not be shaken in East Friesland. And yet the true explanation lies right under their noses! either the neighbor's herd is red-and-white, and one of his bulls has jumped the fence, or else it is a case of atavism such as I have already spoken of. A belief in maternal impression, like a belief in telegony, is a superstition with which no serious breeder will waste time; but it cannot be easily eradicated from the minds of the great mass of farmers, because it has sunk in so deeply."

A proposition which extremists sometimes class with the foregoing, but for which Dr. Wilsdorf shows more tolerance, is the belief in the inheritance of acquired characters. Stockmen, particularly in regions where breeding has been the occupation of the same family through many generations, have amassed rich stores of experience which satisfy them that animals under the influence of better care, feeding and housing change their form and characteristics, and that these changes occurring in the life of the individual are inherited by their progeny. This conclusion, which

[2]This is denied by C. B. Davenport, "Skin Color of Mulattoes," JOURNAL OF HEREDITY, V, 12, 555, December, 1914. The color seems to be due to numerous separate factors which act as units in inheritance. Dr. Wilsdorf might better have mentioned height as a character which shows blending; although in this case too the blending is very likely due merely to the fact that the unit characters involved are too many and too small to permit the observer to see their segregation. —The Editor.

found its first clear expression in the teachings of the zoölogist Lamarck and was in part at least accepted by Darwin, was strongly denied by the zoölogist Weissmann who is followed in this respect by most present day naturalists. The strife between adherents of Lamarckism and adherents of Weissmannism is bitter and continuous, and Dr. Wilsdorf does not think that, on the whole, it is very profitable to the science of animal breeding. Most of the alleged cases of inheritance of acquired characteristics he admits may be dismissed without much hesitation, but he sees others in which the influence of the environment seems to him to be transmitted directly to succeeding generations. "If we observe the well-known Arabian horse at home, we recognize in him a definite type, which is common to the whole breed in Arabia. The Arabs say of him, 'The Arab horse remains an Arab horse only so long as he breathes the air of the desert.' For centuries Arabian horses have been brought to all civilized countries and have astonishingly changed. The English Arab is different from the Hungarian, and both are different from the Prussian or Saxon or French. Whence comes this inherited variability in form, size, looks?

THE SIMMENTALER CATTLE.

"In the Bernese Oberland are the huge and beautifully formed cattle called Simmentaler. These, too, have been carried to all other countries, and at present there exist abroad a multitude of Simmentaler herds which in part, indeed, are similar, but in part show great differences. One more example: on the steppes of Hungary is found a breed of Steppe Cattle, of little value because of its low milk production. The increasing demand for milk has led the Magyars and the Hungarian government to seek in every possible way to increase the milk yield of this breed. High producing cattle from other districts have been brought in; sometimes these have been maintained and further bred pure; sometimes they have been crossed with the native cattle. At first, fine results were secured, but with further generations the newcomers became more and more like the old steppe cattle in form, size and milk yield, until finally the progeny of the North German and Swiss bulls and cows came to be almost exactly like the steppe cattle. Such cases, small or large, can be found in almost any cattle country in the world today."

In conclusion, the author warns his readers, let there be no misunderstanding as to what the science of genetics claims to have accomplished in Germany. Progress has been great —astonishingly great considering the short time involved—but the distance yet to go is still greater. "The question of the inheritance or non-inheritance of parental qualities, the problem of changing the inherited characters of animals during their youth, the maintenance of high fecundity joined to high production, the finding of tests of the fitness of animals for the purposes for which they are desired, the tendency to greater variability in many breeds, the prepotency of the different sexes, the determination of sex of progeny, artificial fecundation, the inheritance of diseases: all these questions and many others have either only been touched, or are wholly unexplored. As Dr. Müller of Tetschen, the founder of the German Genetic Association, aptly said, we stand before riddles,—but riddles whose solution we can attack with more hopeful zeal than ever at the present day; their solution will mean an immense gain to the live-stock breeder, the agriculturist, but perhaps no part of this gain will be greater than the light which will be thrown on the nature of Man himself."

DATE PALM ALLIES IN AMERICA

North American Fan Palms Related to the Genus Phoenix—Several Mexican Species With Date-Like Fruits—Majority of Palm Families Native to New World.

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THE finding of fossil date seeds in eastern Texas is an interesting discovery recently announced by Dr. E. W. Berry.[1] As date palms have been known hitherto only in the Old World, it may be worth while to call attention to the analogies presented by some of the native American fan-palms. The geographical obstacles to the recognition of such an alliance being removed by the discovery of the fossils, two questions naturally suggest themselves. Is the finding of these fossils to be taken as an indication that the date palm, or the genus Phoenix, originated in America, and which of the existing genera is to be looked upon as the nearest surviving relative of Phoenix in America?

It has long been recognized that Phoenix is much more closely related to the fan-palms than to other pinnate-leaved palms. Even the leaf structure shows that there is no alliance with the other pinnate palms, for in comparison with these the pinnae of Phoenix appear to be reversed, or up-side-down, being V-shaped in cross-section, whereas in all other pinnate palms the pinnae are Λ-shaped, as though folded down instead of up. This difference becomes very significant when we recognize the probability that the two forms of pinnae represent different methods of splitting an ancestral undivided, plicate or plaited leaf.

A plicate leaf split along the upper folds or ridges gives V-shaped segments. Splitting along the grooves between the ridges would result in reversed or Λ-shaped segments. These considerations are not altogether theoretical, in view of the fact that the seedlings of nearly all palms have undivided leaves. The mature, compound form of leaves is attained usually by very gradual stages of increasing the number of segments and splitting them apart. In all of the fan-palms that have deeply divided leaves the splitting takes place along the grooves, resulting in V-shaped segments, like those of the date palms.

Hence we may consider that the specialization of the date palm leaf consists mostly in the addition of an elongated rachis or midrib that allows the segments or pinnae to stand well apart, instead of being inserted on a central base, or ligule, like the radiating segments of the fan-palms. The leaves of some of the fan-palms show no indication of a midrib, as in the genus Thrinax and its relatives. But in most of the genera the middle segment of the leaf has a thickened midvein or rudimentary rachis. Some of the American palmetto palms present an intermediate type of leaf structure, with a more strongly developed midrib. The leaves of Inodes are of an oval form, and with a part of the segments inserted on a strong, decurved midrib, as shown in fig. 8. A further development of the midrib, sufficient to separate the segments, would afford a transition to a pinnate leaf, with a structure parallel to the leaves of the date palms. Hence we may say that as far as leaf structure is concerned the genus Inodes offers an analogy with the date palms.

PHOENIX AND PSEUDOPHOENIX.

As the name indicates, the genus Pseudophoenix also presents certain

[1] Fruits of a Date Palm in the Tertiary Deposits of Eastern Texas, American Journal of Science, 37: 403, 1914.

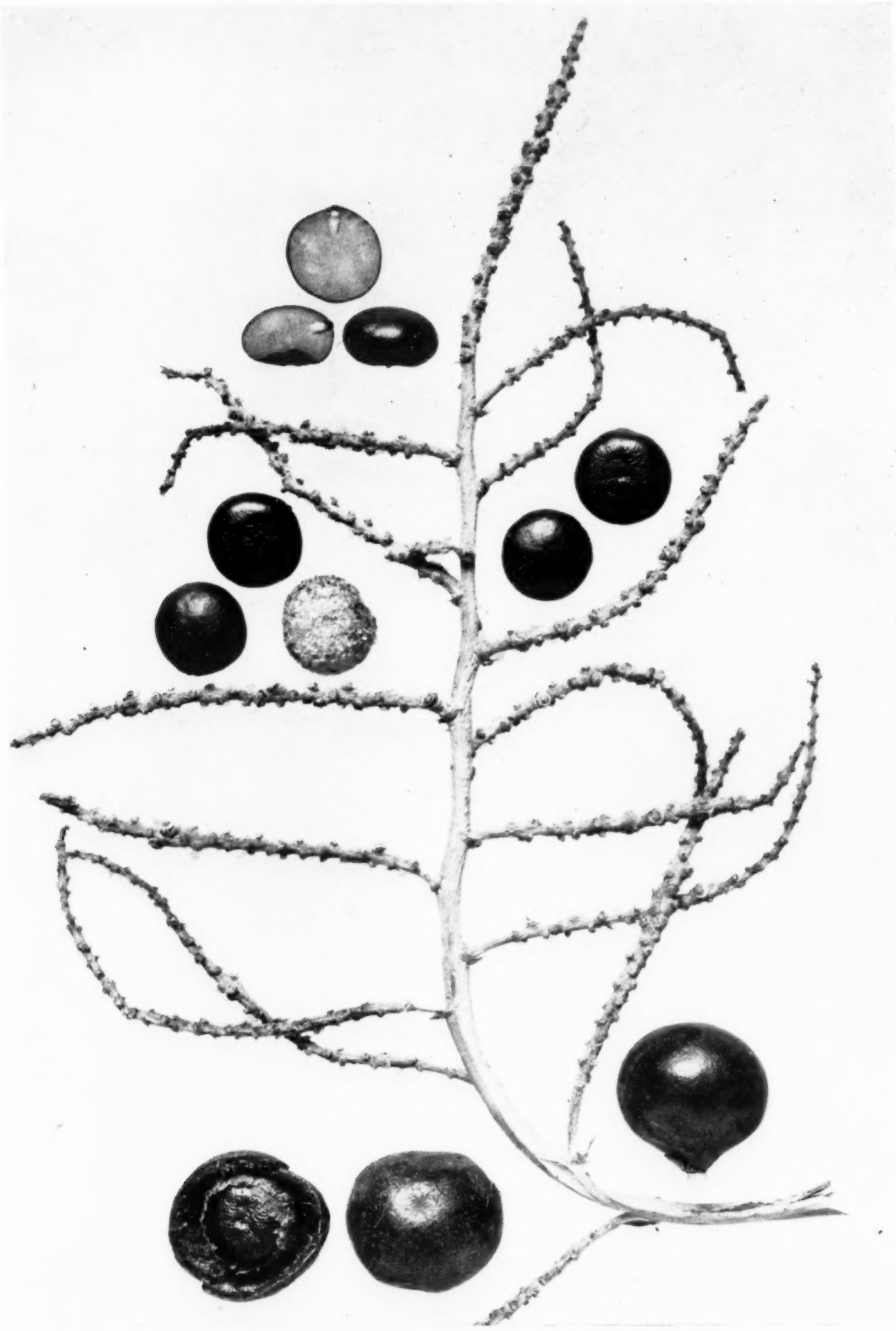
AN AMERICAN ALLY OF THE DATE PALM

If the date palm, which is now confined to the old World, really originated in America, as has recently been suggested, it ought still to have some relatives on this continent. This Mexican palmetto (Inodes) appears to be one of them. It will be noted that many of the segments of the leaves are inserted on a strong, decurved midrib. With a larger midrib or if the midrib were, so to speak, drawn out, the leaf would be elongated and would closely resemble that of the date palm. Photograph by G. N. Collins at San Pablo, Campeche, Mexico. (Fig. 8.)

analogies with the date palms. It is like Phoenix in being more nearly related to the fan-palms than to other pinnate-leaved palms, and may be considered as another independent offshoot from the fan-palms. With respect to the fruits there are distinct points of agreement with other American families of pinnate-leaved palms, more particularly with the coconut palms, ivory palms (Phytelephas), bag palms (Manicariaceae), and wax palms (Ceroxylaceae), but the leaves, inflorescences and flowers of Pseudophoenix are much closer to those of the fan-palms. The similarity to Phoenix lies in the fact that the pinnae are strongly plicate and are inserted very close together in irregular groups or clusters. Nevertheless, the resemblance is only superficial, for the folds or channels of the pinnae are below, as in the other pinnate-palms, instead of above as in Phoenix.

Thus although Pseudophoenix does not appear to have any direct alliance with Phoenix, it has a somewhat analogous relation to the American fan-palms, agreeing closely with them in some respects and diverging widely in others. The structure of the flowers is much like that of the fan-palms, each flower standing separately, on a distinct pedicel. The sexual specialization of the flowers is also very slight, scarcely more than in the fan-palms.

To admit the possibility of American origin for Phoenix would add one more family to the American palm flora, and would still further increase the already striking preponderance of family types in America. Though many botanists have classified the palms in a single family, the genera are numerous and fall into several very distinct groups that should be considered as families. Most of these groups are confined to America.



FRUIT AND SEEDS OF A MEXICAN PALMETTO

The fruit of this species, *Inodes exul*, probably approaches the date as nearly as that of any other palm now found on this continent. Such fruits are gathered in quantities by the Mexicans and form a staple article of diet in some districts. The seeds are surrounded by a layer of edible flesh about one-eighth of an inch thick. Photograph by C. B. Doyle, natural size. (Fig. 9.)

In presenting a summary of the families of palms in 1913, it appeared that 13 families are found on the American Continent and only 5 other families in the Eastern Hemisphere.[2]

If now the date palms are to be withdrawn from the Old World series and added to the New, we shall have the more reason to entertain the idea that this order of plant life had its origin and evolution somewhere on this side of the globe. It is also possible to distinguish a North American series of families from a South American series. To judge from the contrasts presented by the existing forms, North and South America have had separate palm floras for periods that must have been very long in comparison with the time that has elapsed since the continents were joined, for most of the palms that appear to have traveled along the Isthmus have occupied as yet only a small part of the regions that are now accessible to them.

FAN-PALMS WITH SEEDS LIKE DATES.

With these general considerations in mind we can better appreciate the interest of the fact that some of the American fan-palms have seeds rather closely similar to those of the date palm. This is most notably the case with the genus Brahea, where the seed is of the same general form and has a distinct longitudinal groove. The Florida saw-palmetto (*Serenoa serrulata*) also has fleshy date-like fruits, with seeds of the same general shape and external appearance, but lacking the longitudinal groove.

While the seeds described by Dr. Berry could not be referred to the genus Brahea on account of the position of the embryo and the depth of the longitudinal groove,[3] such differences are often found in closely related genera. Neither should too much weight be placed upon the elongate form of the seeds, which gives them so much similarity to the seeds of the familiar commercial varieties of dates. Some species of Phoenix have the fruits almost spherical, and this is true also of some of the varieties of *Phoenix dactylifera*.

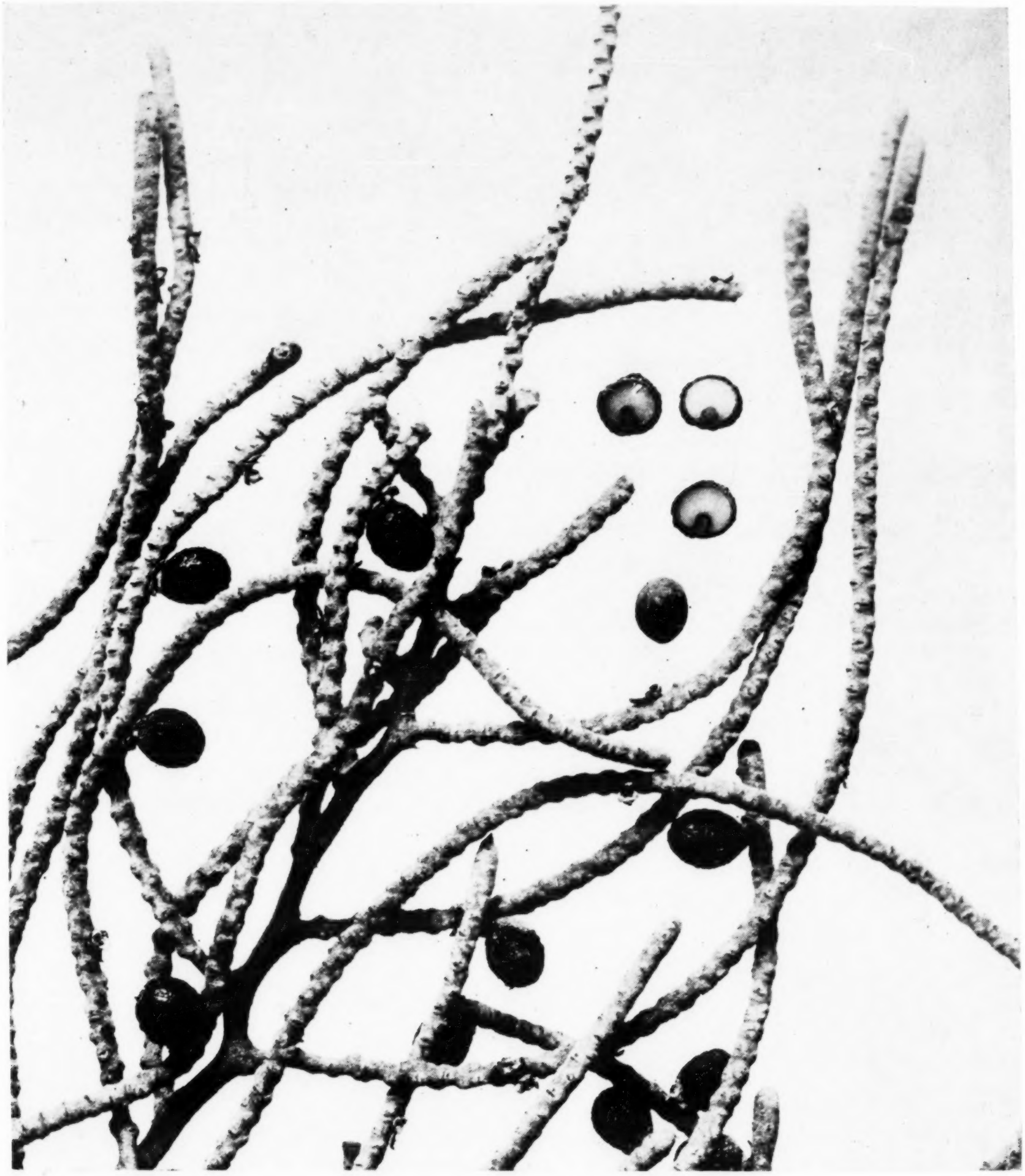
The similarity shown by the seeds of Brahea is at least sufficient to indicate that the form of the seeds is not a unique characteristic of the date palms, but a feature that may have been shared with older relatives now extinct. Unless the fossil remains are of a character to exclude such a possibility it will be easier to believe that the seeds found in Texas may represent some collateral relative of the date, perhaps even a fan-palm, rather than a true member of the genus Phoenix. Dr. Berry appears to have provided for this contingency by naming his fossils as *Phoenicites occidentalis*, instead of referring them to the genus Phoenix. Fossil palm leaves have been found in many localities in the western States, and even in Alaska. The fact that these were fan-palms need not be supposed to exclude the possibility that some of them may have borne date-like fruits, or that they may have spread as fan-palms to the Old World. The Polynesian fan-palms that have been described under the name Pritchardia and the Asiatic genus Livistona appear to have rather close relatives among the American fan-palms.

PRIMITIVE AMERICAN PALMS.

If the date palms originated in America or reached this continent at some later period it is difficult to understand why they should have become extinct, in view of the fact that some of the most primitive types of fan-palms have continued to exist in Florida, the West Indies and Central America. Moreover, a considerable number of the related American fan-palms, including such genera as Inodes, Brahea, Erythea and Washingtonia, live in open, desert regions, and have the same habits and ecological requirements as the date palms. The similarities extend to the production of fruits with fleshy, edible pericarps, not as thick or as sweet as those of the date palms, but neverthe-

[2] Cook, O. F., Relationships of the False Date Palm of the Florida Keys, with a Synoptical Key to the Families of American Palms. Contr. U. S. Nat. Herb., vol. 16, pt. 8, 1913.

[3] Drawings of the seeds found by Berry were published in the JOURNAL OF HEREDITY, V, 11, 499, Nov., 1914.



A MEXICAN RELATIVE OF THE DATE PALM

The belief that the date palm was an American species a million or more years ago is based on finding fossil seeds in Texas. This photograph of part of the inflorescence of a Mexican palm, *Brahea dulcis*, shows that some of the present American palms have seeds very much like those of a date, including the groove along one side, which is clearly shown in the cross sections of three seeds in the upper part of this plate. It is possible, therefore, that the seeds found in Texas were not those of the date palm, but of some ancestor of one of the present American genera like Brahea or Inodes. Photograph by C. B. Doyle, natural size. (Fig. 10.)

less used by the native Mexicans, and recognized by botanists in such names as *Brahea dulcis* and *Erythea edulis*. The fruits of *Inodes texana* or a closely allied species are eaten like dates and are an article of trade in the native markets in the Tampico district. The Indians of the Colorado desert in southern California think of the date palms that are now being planted by the white settlers as a superior kind of Washingtonia.

In one important respect the fruits of Inodes are the most like dates, for they have only a thin membranous endocarp while the other genera have a hardened

shell-like endocarp around the kernel, as may have been the case with the fossil seeds described by Dr. Berry, to judge from the following statement in the description of the fossil:

"The surface is longitudinally wrinkled, due possibly to desiccation before preservation, which may also make the dimensions as given probably under what they were in life. The flesh was relatively thin compared with that of the cultivated date and must have been of considerable consistency and fibrous rather than of the soft and almost fluid character of some of the modern varieties of the latter."

The very wide distribution of the species of Phoenix in the Eastern Hemisphere makes it the more difficult to credit a complete extinction of the group in the Western Hemisphere. Date palms are known from all of the tropical and subtropical regions of the Old World, from India through Africa to the Canary Islands, though they do not extend far into the Chinese region, to Australia, or to the islands of the Pacific. This is in contrast with the distribution of the Asiatic fan-palms, which are well represented in eastern Asia and the Pacific islands. With the possible exception of Raphia, no other genus of palms is so widely distributed as Phoenix, either in the Old World, or in the New. The only competitors in this respect are the palms that may have had human assistance, such as Cocos, Acrocomia, Attalea and Inodes. The last is the most ubiquitous in the wild state in the American tropics, and in this respect also may be considered as the American analogue of Phoenix. These two genera enjoy to a greater extent than most of their relatives the same adaptive advantage, that the seeds retain their vitality for long periods in the dry state. With most palms drying the seed soon kills the enbryo.

The relations of Phoenix with the Old World fan-palms might also have bearing upon the place of origin. Students of palms have generally agreed that Phoenix is most closely related with Chamaerops, a genus confined to the Mediterranean region, the Asiatic species formerly included in Chamaerops being assigned by recent authors to Trachycarpus. Chamaerops has larger and more date-like fruits than Trachycarpus, and stronger spines on the petioles. The production of hybrids between the date palm and Chamaerops has been claimed, but is difficult to credit in view of the numerous structural differences between the two palms. The date palm differs from all of the related fan-palms in having the sexes on separate plants, and in having the inflorescence highly specialized. The branches are mostly simple, and are arranged in clusters or whorls, a condition that may have been attained by uniting the basal joints of the primary branches with the main axis. Another profound difference is the reduction of the spathes to a single one, which encloses the entire inflorescence until the time of flowering.

If the fossil seeds from Texas represent a true date palm, it may be expected that remains of other Asiatic genera of fan-palms will be found in America. On the other hand, if the fossils represent a collateral relative of the date palm the separation between Phoenix and the Old World fan-palms may have occurred in the Eastern Hemisphere. In view of the analogy presented by Brahea, the former presence of Phoenix in America can hardly be determined from the seeds alone. Other parts of the plant are needed to make the identification secure. It is to be hoped that nothing in the way of palm materials will be overlooked by those who have the opportunity to collect fossil plants in the Southwestern States.

WHEAT BREEDING

Many Genetists Working With Important Cereal Crop—What They Have Accomplished—Hope for Future Improvement—Methods of Procedure.[1]

A. E. V. RICHARDSON

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SYSTEMATIC breeding of wheat and other cereals has been practised for many years past in the United States, Canada, Germany, France, Sweden, Britain, and India.

A large number of agricultural experiment stations and colleges in the United States are at present engaged in breeding new varieties of wheat. The Minnesota station has originated numerous varieties, two of which have "yielded from 1 to 3 bushels more per acre than the varieties formerly grown."[2] Other stations, particularly Maryland, North Dakota, California, and Ohio, have done much valuable work in the production of new varieties and the improvement of existing types.

In Canada most of the breeding and selecting of wheat has been done in connection with the Dominion Experiment Farm system on the central station at Ottawa. The late William Saunders began the work of wheat improvement in Canada in 1888. Working on the Red Fife wheats, he succeeded in producing the cross-bred varieties Stanley, Preston, Huron, Marquis, and Bishop, which are now widely grown throughout Canada.

In England, Biffen of Cambridge has done a large amount of work in wheat improvement, paying special attention to the production of a variety of wheat combining the important qualities of (*a*) high yielding capacity of the English varieties; (*b*) the high strength characteristic of the Manitoba wheats; and (*c*) immunity from yellow rust (*Puccinia glumarum*). He claims to have achieved considerable success in this direction.

In Sweden, the wheat breeding is concentrated at Svalöf under the direction of the Swedish Grain Society. This society has done a vast amount of good in introducing superior varieties of wheat in Swedish agriculture. No less than fifteen trained plant specialists are engaged in this work. Details of this institution will be discussed later.

In Germany, a large number of public and private institutions are engaged in the improvement of cereals and root crops. According to Hillman,[3] there are no less than 84 breeders engaged on the improvement of wheat, 46 of rye, 65 of barley, 53 of oats and 44 of fodder and sugar-beets.

A considerable amount of work has been done in India towards the improvement of local wheats by selection and crossing.

WHEAT BREEDING IN AUSTRALIA.

The outstanding feature in wheat-breeding work in Australia is the remarkable success achieved by that patient and retiring genius, the late William Farrer, of New South Wales, in every branch of wheat improvement.

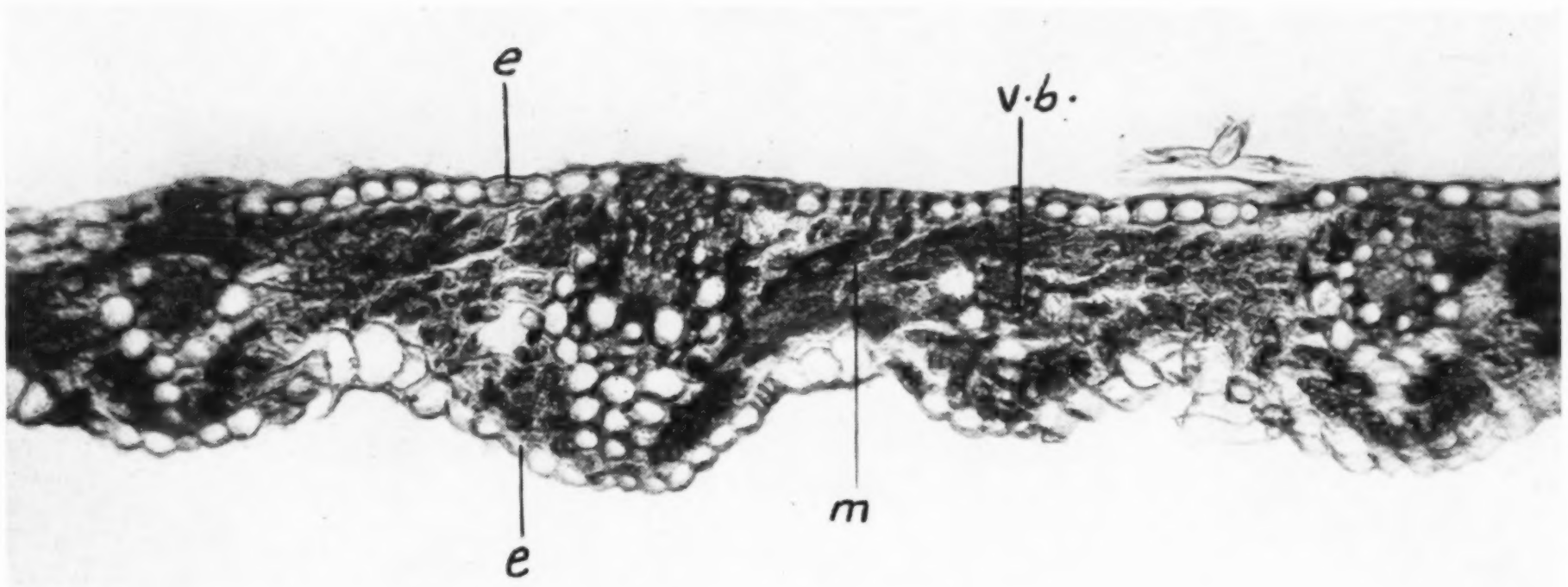
A man who could set out as clearly and comprehensively as Farrer,[4] both the goal toward which he was striving in his work of wheat improvement, and the methods whereby he hoped to

[1] Parts of a paper read before the Australasian Association for the Advancement of Science, January, 1913; published in altered form in Bul. 22, n. s., Victoria Department of Agriculture.

[2] Year-book of the U. S. Department of Agriculture 1908, p. 155.

[3] P. Hillman, Arb. Deut. Landw. Gesell. (1910) No. 168.

[4] Farrer: The making and improvement of new varieties of wheat for Australian conditions. *Agricultural Gazette* (N.S.W.), February, 1898.



CROSS SECTION OF A WHEAT LEAF

Above and below, the leaf is bounded by a single layer of epidermal cells (*e*), between which lies the main mass of the leaf cells, the mesophyll. "The upper portion of the mesophyll is typically closer in structure than the lower portion, which is usually spongy in character and contains a large number of intercellular spaces. These intercellular chambers form labyrinthine spaces in which air circulates freely in the interior of the leaf. Scattered t rough the body of the mesophyll are the vascular bundles (*v.b.*) which form in wheat a set of parallel strands serving not only as skeleton for the support of the remaining leaf tissues, but also as media for the conduction of sap to every part of the leaf." Photograph highly enlarged. (Fig. 11.)

reach that goal, and in less than a decade flood the market with varieties like Federation—the most prolific and popular farmer's wheat in the Commonwealth; Bobs and Comeback—of unsurpassed milling excellence; Florence and Genoa—bunt-resisting varieties; and a host of others enjoying widespread popularity, such as Bunyip, Thew, Bayah, Warren, Genoa, Firbank, Cleveland, Cedar, Jonathan, etc., must have possessed in an unusual degree the insight of genius. It is no exaggeration to say that Farrer has added millions sterling to the national exchequer by the creation of Federation wheat. Dr. Cherry estimates the cash value of Farrer's work to Victoria alone during the 1909 season at £250,000. Since that estimate was framed, the area sown with this popular variety in Victoria has greatly increased, and the benefits have become commensurately greater.

Farrer's work was continued by G. L. Sutton, late Wheat Experimentalist of New South Wales, who did a great deal to popularize the Farrer varieties amongst farmers.

In this State, H. Pye, the present Principal of Dookie Agricultural College, has been the most prominent investigator of the problems connected with the improvement of wheat varieties. For many years he collaborated with Farrer in the testing of new varieties, and the independent work he has done has resulted in the production of a number of crosses possessing improved qualities, which are now undergoing the process of fixing and testing on a commercial scale. The work of producing new varieties of value is necessarily slow and tedious, and the results of Mr. Pye's long and patient work will doubtless be of immense benefit to wheat-growers.

In South Australia, the improvement of varieties by selection and cross-breeding is carried out at the Parafield Wheat Research Station and at the Roseworthy College. The demand for improved and selected cereals from both these centers has for many years past greatly exceeded the supply.

Many of the varieties grown in the wheat areas of the Commonwealth were originated by private farmers. With one or two exceptions, these varieties were obtained by selection from the ordinary crop. Among many of the varieties that might be mentioned are Dart's Imperial, Marshall's No. 3, Correll's No. 7, King's Early, Yandilla King, Steinwedel, Petatz Surprise, Carmichael's Eclipse, and Huguenot. In

most cases these varieties originated from a single plant growing in the ordinary field crop. The outstanding qualities of these plants arrested the attention of the originator, who harvested them separately, and multiplied the seed for distribution.

OBTAINING IMPROVED VARIETIES.

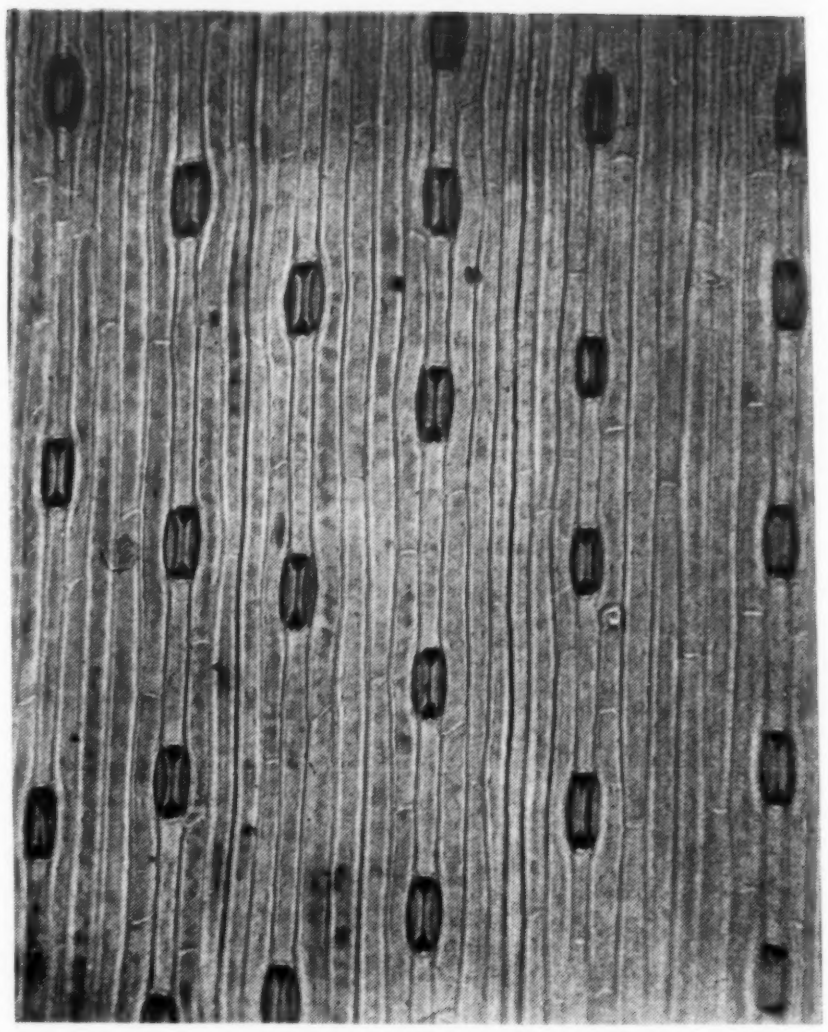
There are two general methods by which improved and new varieties may be obtained, namely, by—

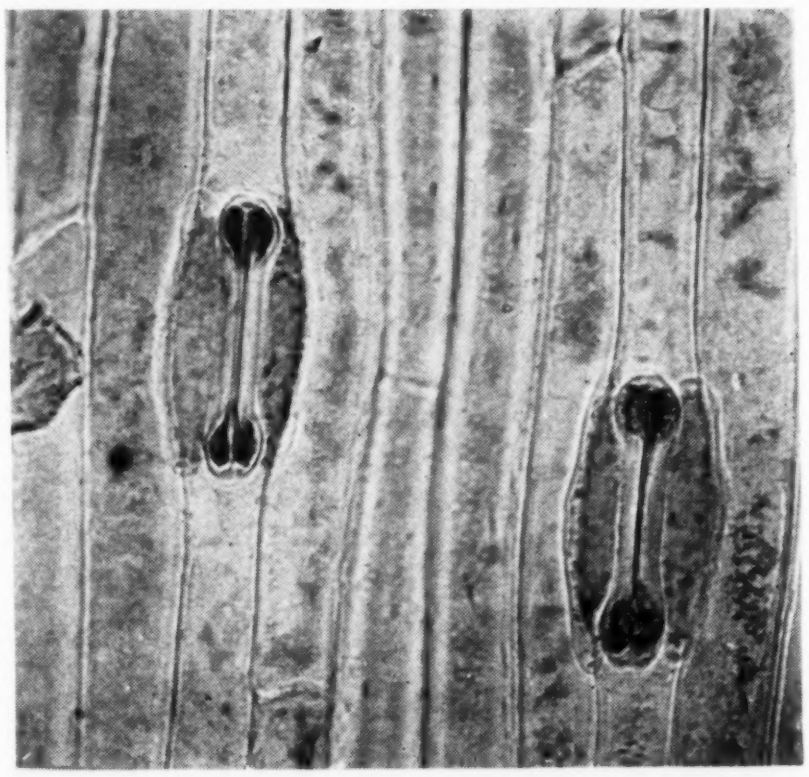
1. Selection.
2. Cross-breeding.

We will consider each of these in some detail.

Vilmorin, a renowned authority on plant breeding, states that "selection is the surest and most powerful instrument man possesses for the modification of living organisms." Reduced to simplest terms, it consists merely in the choice of the best individuals for the propagation of seed, and it is by means of selection exercised through centuries that our cultivated plants have reached their present standard of excellence. The obvious effects of selection may perhaps be seen to best advantage in the animal world. It was by patient, systematic selection, exercised over a long period of years, that the famous Booth and Bates types of Shorthorn cattle were developed. What we term pedigreed stock in Merinos, Clydesdales, Jerseys, etc., have been produced by a slow, painstaking process of selecting the very best animals in the herd, accompanied by a vigorous exclusion of the culls. While the vast majority of farmers are well aware of the beneficent effects of selection in the animal world, they appear to be totally oblivious of the fact that selection can be equally effective when applied to the plant world.

The term "selection," as commonly used, covers a general, as well as a specific, idea. In its general sense, selection is practiced by every good farmer when he chooses varieties of wheat that are best suited to his soil and climatic conditions, reserves the best portion of his crop for seed purposes, and takes good care to grade his seed well. No well-informed stock breeder would think of selecting as his parent stock





HOW A LEAF BREATHES

Above, epidermis of Federation wheat (under surface of leaf), showing the stomata or breathing pores. "Each stoma or pore consists of two sausage-shaped guard cells joined together at the extremities in such a manner as to leave a very narrow slit-like pore between them." The stomata open and close in accordance with the respiratory needs of the leaf, this movement being brought about by changes in the curvature of the guard-cells, which in turn depend on the turgidity or water content of the ells. Below, the same further enlarged (to about 300 diameters). (Fig. 12).

any other than the best animals he can secure with the means at his disposal. Nor should any wheat farmer be satisfied with anything but the best of his crop for seed purposes. He should take the greatest pains to get, first, the right variety of wheat; second, well-developed seed; and third, the seed should be secured from the most vigorous plants. The latter point is very important.

WHAT THEY ARE WORTH.

With regard to the choice of varieties, it may be pointed out that the difference in yield between two varieties of wheat grown on the same farm, under precisely similar soil and climatic conditions, is frequently sufficient to pay the rent and interest on the land on which the crop was grown. This has been demonstrated time and again in departmental experimental plots and on private farms.

Carefully-conducted experiments in various parts of the world demonstrate that it pays a farmer to give careful attention to the selection of his seed.

In Canada, Zavitz[5] states that during twelve years' work at the Ontario Agricultural College, large, well-developed grain of winter varieties of wheat averaged 46.9 bushels per acre, as against 39.1 bushels from small shrunken seed, and with spring wheat the average yield from the well-developed, plump seed was 21.7 bushels, as against 16.7 of the small seed.

In Britain, the University College of Wales[6] reports that nearly double the yield was obtained from plump grain as against small grain.

Desprez, in France,[7] after experimenting with a large number of varieties of wheat, draws the conclusion that the results are markedly in favor of large seed.

Cobb (N. S. W.),[8] after an exhaustive comparison of seed wheat from 24 varieties, states that the increased yield obtained from well-graded seed is sufficient to justify the installation of first class cleaning machinery.

The results obtained at some of the American Experiment Stations are conflicting, but, wherever care was taken in the selection of seed, considerable increases in yield resulted. This was the case at Kansas, Nebraska, North Dakota, and Indiana experiment stations, whilst at Pennsylvania and Ohio no marked increases resulted.

From these various experiments it may be safely concluded that the best results will be obtained by the selection of well-developed, plump seed, from plants of strong vitality.

The term selection is generally more restricted in meaning. It has now acquired a technical significance, and implies the systematic choosing of specific wheat-plants for future reproduction, with the object of bringing about an amelioration of type. It recognizes that there are endless variations of type in an ordinary wheat crop —that there are grades of quality in wheat just as there are grades of quality in fruit and butter.

Selection seeks to isolate those types of plant which approximate most nearly to the ideal, and systematically to choose from the produce of these types the variations which are likely to be of material value.

This is the manner in which most of the improvements in our field crops have occurred.

TWO KINDS OF SELECTION.

Of course, many of the modifications effected in plants, through long years of cultivation, are the result of unconscious improvement. This is exemplified by the development of the cabbage, cauliflower, and kohl-rabi from the woody perennial plant *Brassica oleracea*, which is a native of Southern Europe. The cabbage is a modification of the leaf, the cauliflower of the inflorescence, and kohl-rabi of the stem of this plant, and their origin is due to long-continued selection of variations which were considered desirable, and not because the gardener consciously

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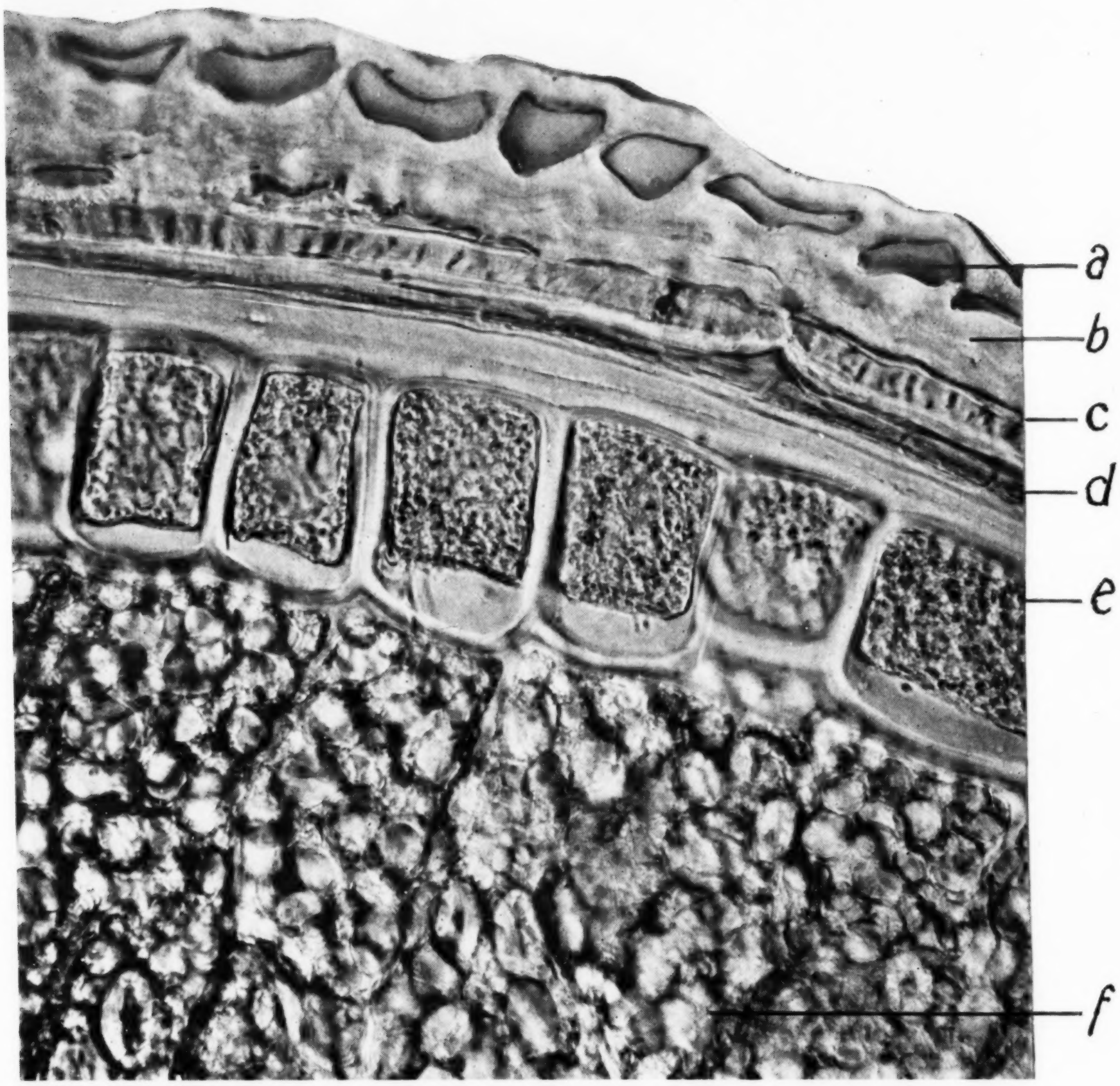
[5] Zavitz: *Journal of the Board of Agriculture*, June, 1910, p. 35.
[6] Report of University College of Wales, 1899, p. 68–70.
[7] Jour. Agri. Prat. (1897).
[8] Cobb: *Agricultural Gazette*, New South Wales, 1903.



A GRAIN OF "FEDERATION" WHEAT

Transverse section, enlarged about 400 times. The structures shown are as follows:

(*a*) The *epidermis*, which consists of a layer of longitudinal cells with their long axes in the direction of the length of the kernel.

(*b*) Second layer, the *epicarp*, very similar to the former in general appearance resting on an irregular layer apparently devoid of cellular structure.

(*c*) The *endocarp*, placed at right angles to the cells above described. In cross section the cells of the endocarp appear to be very regular in character, with thick cell walls which in longitudinal section display minute pits.

(*d*) The *testa*, consisting in the unripe kernel of two distinct layers of cells closely applied to the aleurone layer. The testa is very tough in charater, not readily permeable to water and homogeneous in structure.

(*e*) The *aleurone* layer, consisting of large more or less rectangular cells, with thick cell walls containing oil and granular nitrogenous matter. It is frequently called the gluten layer, though this is a misnomer, as the gluten found in the flour is derived from the starch cells of the endosperm and not from the aleurone layer.

These five layers constitute the *bran*, and are usually removed when the wheat is milled. Beneath them are (f) the starch granules, which are ground up to make white flour. (Fig. 13.)

attempted to evolve these specific forms.

On the other hand, many instances might be quoted in which improvement has been effected by systematic breeding.

Perhaps the most striking case is that illustrated by the development of the sugar content in beets. By a process of careful, repreated, and systematic selection of individual plants of high sugar content, combined with the repeated testing of the hereditary powers of each individual plant, the common beet, containing from 6 to 7% of sugar, has been developed into the sugar beet, containing from 20 to 25% of sugar.

The value of this improvement must be obvious. It has enabled the beet-sugar industry in Europe and America to more than hold its own against the cane sugar produced by black labor in the Tropics.

A remarkable case of selection is referred to in De Vries'[9] work. In 1886, De Vries found at Loosdrecht a plant of clover bearing a few leaves with four and five leaflets. He commenced some experiments to fix this type of clover. By continuous cultivation and selection, he ultimately (1892) secured plants in which four and five leaflets on each leaf were common, and, strangely enough, for the first time several leaves appeared with six and seven leaflets.

It is very probable that no clover plant in the world ever possessed six or seven leaflets until De Vries commenced these experiments.

HISTORY OF WHEAT SELECTION.

The idea of improving cereals by selection is of comparatively recent origin. The most notable of the early wheat-breeders were Le Couteur, of Jersey; Shireff, of Haddington; and Hallet, of Brighton.

Le Couteur, nearly a century ago, observed that an ordinary field of wheat appeared to be extremely variable, and concluded that some of the various types found in the growing crop would yield better than others. He isolated 23 distinct types, and grew them separately, and was successful in introducing several new varieties into general cultivation. One of these is still grown under the name of Talavera.

A Scottish agriculturist—Patrick Shireff—developed the celebrated Hopetown oats in 1832, and placed on the market four distinct varieties of wheat, all of which were extensively grown in his time. His method of procedure was to walk through his wheat fields at harvest-time, and mark any plants which stood out prominently from the surrounding plants. He isolated these plants, sowed them separately, subjected them to severe tests, and sold the seed of the most promising types.

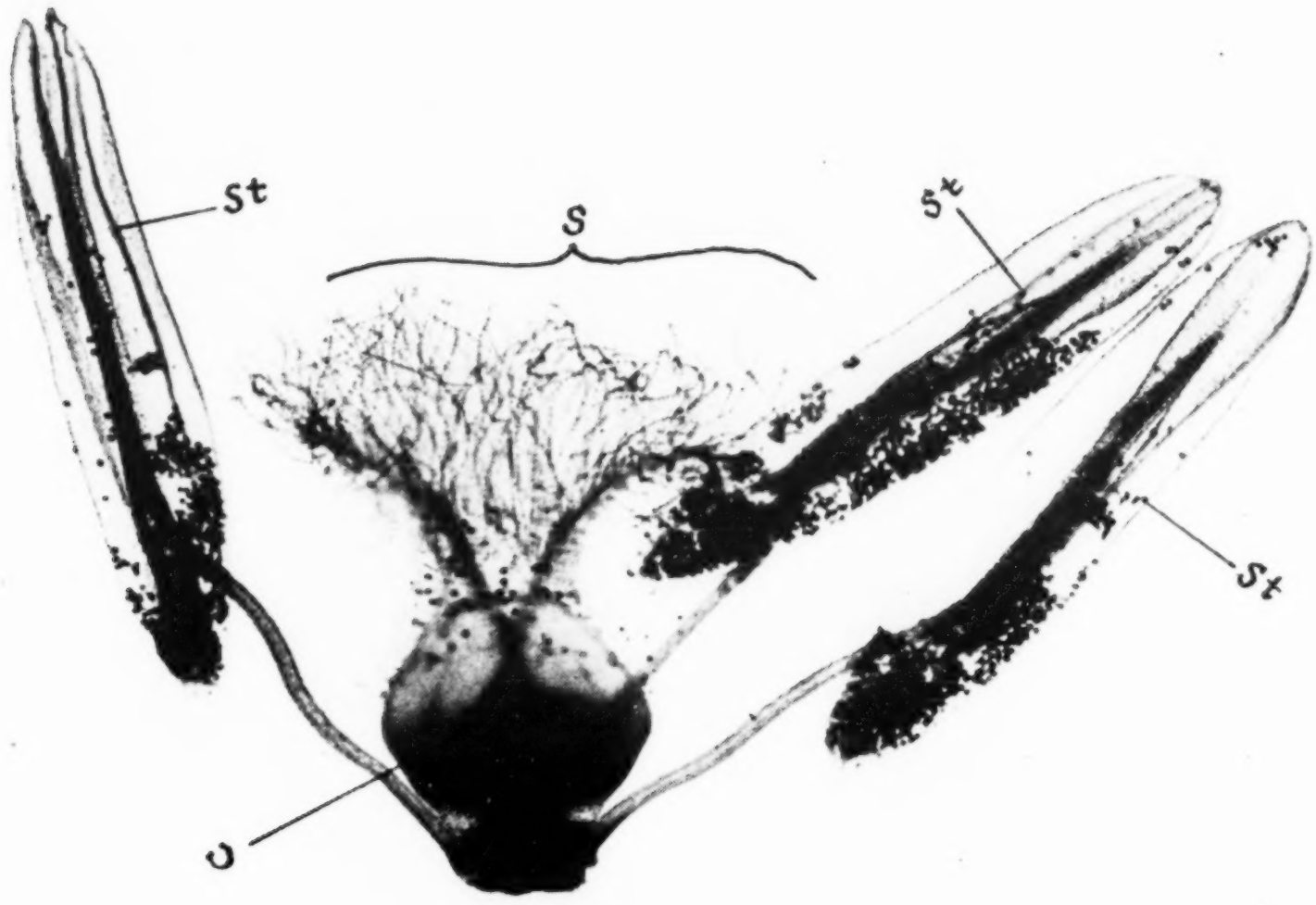
It is very interesting to note that neither of these breeders adopted the principle of *repeated* selection. They simply isolated individual plants of promising appearance, and multiplied the seed of these types as rapidly as possible. There was but one initial selection, followed by rapid multiplication of the progeny. On this fundamental point they differed widely from Major Hallet, who began his work of selection in 1857. His method of selection was derived from his previous experience of breeding Shorthorn cattle.

He first introduced the principle of repeated selection. His method was to select each year the best grain from the best ear of the best plant he could find in his wheat-field, and to repeat this process for a number of generations On 18th June, 1862, he inserted a full-page advertisement in the *Times*, describing his methods of breeding wheats. In this advertisement he states that his "pedigree wheat was bred upon the same principle of *repeated* selection which has produced our pure races of animals."

During his first five years' work, the length of the head was doubled, the number of grains in the head trebled, and the tillering capacity was increased fivefold.

The improvements effected were, in a measure, artificial, inasmuch as he grew his selected plants on the very best and richest garden soil. Nevertheless, his strains were a success, and greatly improved the harvests of his generation.

[9] De Vries: "The Mutation Theory," Vol. II., p. 36 (1910).



FLOWER OF WHEAT, MUCH ENLARGED

The ovary (*o*) contains the minute ovule or egg cell which, when fertilized by a pollen grain, will develop into a grain of wheat. From the ovule arise the feathery styles (s), whose function is to catch the pollen grain and give it access to the ovary. The stamens (*st*) are three in number, each one consisting of a slender stalk—the filament—bearing at its summit the anther or pollen sacs, which in this case consist of four longitudinal chambers containing large numbers of pollen grains (sperm cells). Normally these pollen-grains fall directly on the styles below, so the wheat flower is self-fertilized; but to serve his own purpose the breeder removes these anthers, and introduces pollen from some foreign source, thus ensuring cross fertilization. (Fig. 14.)

The same principle of repeated selection has since been very largely practised in Germany, and has been very successful. Rimpau, in particular, has applied this principle of gradual improvement by continuous selection to rye, and succeeded in developing the famous Schlanstedt rye, which is now grown throughout France and Germany.

THE SVALÖF METHOD.

Finally, it is necessary to consider briefly the method of selection adopted at the famous Swedish Experiment Station at Svalöf, Sweden. It may be explained[10] that this station owes its origin to a small coöperative village company, formed in 1886 by private farmers for the production of improved seed wheat, oats, and barley, and the testing of new and foreign varieties of grain.

R. B. Greig,[11] one of the members of the Scotch Commission who visited Australia in 1911, gives a most interesting account of a visit to this remarkable institution. He says: "The work at Svalöf is based on two discoveries—first that among the farm crops there exist an indefinite number of elementary species which breed true; and secondly, that superior individuals among these species can be quickly recognized by certain morphological characters. The first discovery was almost an accident; the second was the result of painstaking and minute investigation, assisted by an elaborate system of record keeping.

[10] For a fuller account see Plant Breeding in Sweden by H. Hjalmar Nilsson. JOURNAL OF HEREDITY, V, 7, 281, July, 1914.

[11] Vide *Journal*, Board of Agriculture, London, August, 1910, p. 280.

"By a comprehensive series of trials, the principle was firmly established that the proper unit of selection is the single ear or head. Further investigation brought out the fact that in an ordinary field of oats, wheat, or barley there were dozens of different types, most of which bred true. The next step was to discover the superior types, or those specially adapted for special conditions. It has been demonstrated that certain characters of apparently negligible importance are actually trustworthy indicators of the productive power of an individual and of its quality. This principle of correlation or association of characters has been found applicable to all farm crops, and while it sheds a brilliant light to guide the improvement of crops, and provides a short cut to success, it effectively bars any but the trained specialist from the speedy recognition of new varieties by selection."

There are two general methods of selection adopted by plant-breeders—*mass* selection and *individual* selection.

Mass selection consists of the continuous and repeated selection of a number of the best grains, ears, or plants. It is based on Darwin's conception of the origin of species, and it is supposed that by the repeated selection of a number of élite plants each year, the race, as a whole, will be gradually improved.

De Vries denies that any permanent improvement can result from mass selection.

Fruwirth, on the other hand, affirms that mass selection does result in permanent improvement.

The effect of mass selection, as applied to oats, barley, and potatoes, has been strikingly demonstrated by Professor Zavitz at Ontario.[12] The following table summarizes the results of sixteen years' continuous mass selection on these crops:—

AVERAGE YIELD IN FOUR YEAR PERIODS IN BUSHELS PER ACRE OF OATS, BARLEY, AND POTATOES, SHOWING THE EFFECT OF MASS SELECTION ON SELF-FERTILIZED AND ON VEGETATIVELY PRODUCED CROPS:—

Crops.	1890–93.	1894–97.	1898–1901.	1901–05.
	Bushels	Bushels	Bushels	Bushels
1. Oats—Average for 8 varieties.....	74	79	83	100
2. Barley—Average for 8 varieties.....	50	54	63	63
3. Potatoes—Average for 8 varieties....	120	216	218	249

Mass selection is most effective when the individual plant is made the unit of selection, and not the individual ear or the individual grain, for it frequently happens that large grains and large ears of wheat are found on relatively poor plants.

Mass selection thus practised tends towards improvement of the type by propagating from the best plants and excluding all the rest. It may, of course, happen that some of the selections thus made are superior because they have been grown under favorable environment. They may, for example, have received an extra amount of superphosphate through the irregular working of the drill, or they may have been favored with more space to develop than the majority of plants in the crop. However, the repeated and rigorous selection of the best plants would gradually confine the choice to what might be termed the permanently superior plants, and the general character of the crop would gradually improve in the desired direction.

Mass selection has been practiced with great success at the German experiment stations, and by such breeders as Rimpau, Drechsler, and Mokry. There are several different ways in which this method of selection may be applied. Whatever method is adopted must

[12] Report, Ontario Agricultural College, 1905.

obviously involve as little labor as possible, and take up a minimum of time. To be completely effective, the selection must be continuous and uninterrupted, *i. e.*, the selection must be kept up year after year to counteract any tendency on the part of the wheat to degenerate.

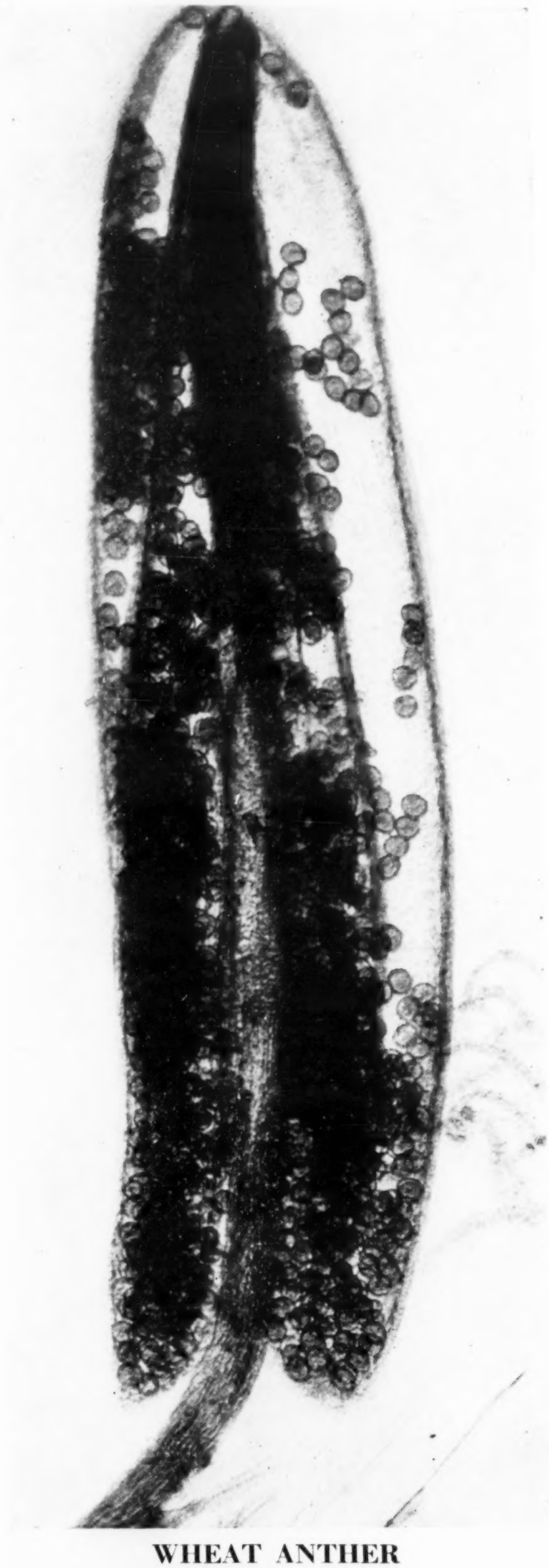
A method which has the merit of being continuous and of requiring a small amount of labor is the following:—

A field of the variety which it is desired to improve by mass selection is carefully inspected at harvest-time, and sufficient of the best-developed heads from robust, well-developed, prolific plants is selected to yield, on hand-threshing, about five pounds of graded grain. This seed may be sown at seed-time, say in 1915, in one strip of the drill, on approximately one-tenth of an acre, as a "stud" plot. At harvest-time a similar process of selection of the best heads from the strongest plants in the "stud" plot is carried out, and the produce of the selection is reserved to form the "stud" plot of 1916. The balance of the "stud" plot of 1915 is harvested and sown as the "seed" plot of 1916 on an area of approximately two acres. In 1916 the process is repeated. The best selected heads of the 1916 stud plot become the stud plot for 1917, and the balance of the stud plot becomes the "seed" plot of 1917. The 1916 seed plot of two acres is harvested and sown on, say, 30 to 40 acres as a "bulk" plot for 1917, from which seed for the whole farm is obtained. Thus, after three years, the selection becomes automatic. The small stud plot has been selected for three years, and represents the "élite" plants of a race which is gradually approaching a pedigreed character.

The full effects of the process would not be felt for at least three years—the time taken for the "stud" plot to become the "bulk" plot.

INDIVIDUAL SELECTION.

The method could be made more systematic by making the unit plot a single row of specially-selected plants, and rigorously selecting each season the very best plants of each row.



WHEAT ANTHER

It is made up of four pollen-sacs, which are about ready to burst at the lower ends, releasing the translucent pollen grains that are visible inside, and letting them fall on the stigma below. (Fig. 15.)

When the individual plant or ear is made the starting point, we have what is known as individual selection. In this case the selection commences with a number of superior plants of a given variety, and the seeds from each plant or ear are separately planted, and kept under continual observation. This enables a strict comparison to be made of the progeny of each selection, so that in a few years the best strain in the original selections may be determined and multiplied for future use.

Nilsson, at Svalöf, after subjecting the older methods of mass selection to a critical examination, decided to adopt the method of single-plant selection used by Shireff and Le Couteur, and has achieved a considerable amount of success. The method of procedure has already been described. As a principle, it is based on De Vries' conception of the origin of species, and it assumes that repeated selection is unnecessary.

Another example of individual selection is afforded by the method introduced by Willet M. Hays, founder of the American Genetic Association. His method consists in isolating the most promising types of plants in a crop, and of testing the efficiency of the selection by comparing the prolificacy of the 100 plants derived from each of the strains so isolated.

For this purpose the produce from individual plants are sown in "centgener" plots. One hundred and forty-four seeds of each selection are sown in a square, with 12 seeds along each side. At harvest-time the outside border row is removed, and the remaining 100 plants are harvested, and the total produce obtained is taken as a measure of the prolificacy of a given strain.

Hays made a close study of variation in wheat, and found that those characters such as yield, which can be expressed in numbers, follow what is known as Quetelet's Law of Variability.

A simple illustration of Quetelet's law may be obtained by comparing the measurement of the height of 1,000 men of the same nationality. If 1,000 men be selected at random and arranged in a row in order of height, it will be found—

(*a*) the man in the middle of the line represents the average height of all men;

(*b*) a line drawn over their heads will diverge only very slightly from the horizontal throughout its entire length, falling gradually towards the end where the smaller men are placed;

(*c*) the line will rapidly curve upward near the upper end of the line where the tall men are placed, and will curve rapidly downward at the lower end where the shorter men are standing.

Hays[13] points out that if the individual yields of a large number of wheat plants of any given variety are arranged in order, a precisely similar curve may be obtained to that illustrated above. The great majority of the plants give only an average yield, a few give a very poor yield, and a few give an exceedingly high yield.

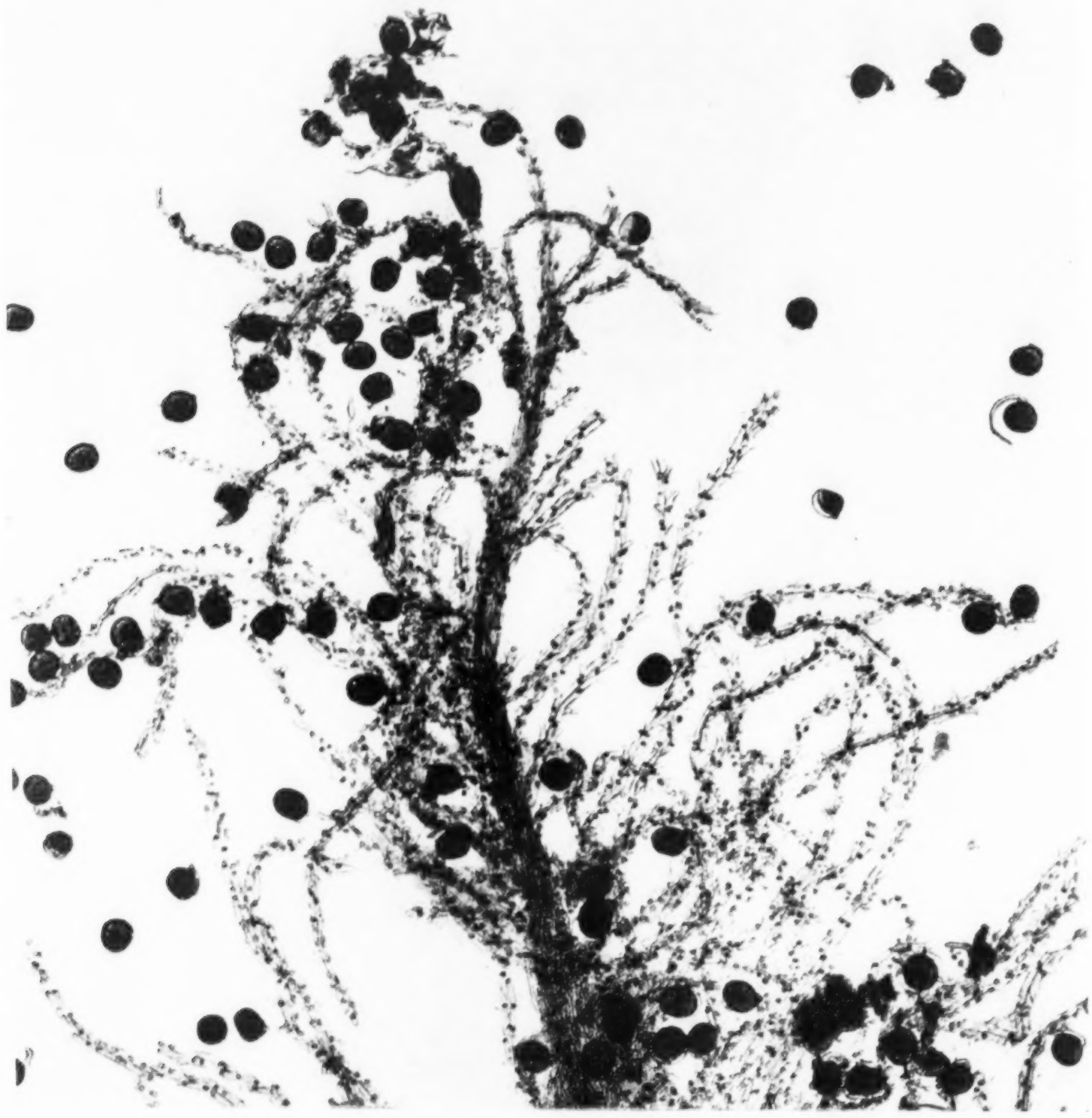
These latter are the plants which he uses for his future selections.

Hays states that in "each 1,000 plants of wheat there are a few phenomenal yielders, and the method of single seed planting makes it practicable to secure these exceptional plants, and from these new varieties can be made."

HAYS' PRODUCTION.

Working on Fife and Bluestem varieties of wheat, which were largely grown in Minnesota, he succeeded in producing improved strains which gave yields of 15-20% more than the original types, and which have largely displaced them from general cultivation. Thus Minnesota 169 wheat was bred by a process of selection from a Bluestem variety commonly grown in Minnesota. During four consecutive years it averaged in field trials 4.9 bushels more than the parent type. In 1902 it was distributed in four-bushel lots to 375 farmers, and reports showed that its average yield in 1903 was 21.5 bushels, as compared with 18.2 bushels average for the common varieties, *i. e.*, an increase of 3.3 bushels, or 18%. Hays judges the efficacy of a given selection, not by

[13] Bulletin 62, Minnesota Experiment Station, U. S. A.



STIGMA OF WHEAT FLOWER

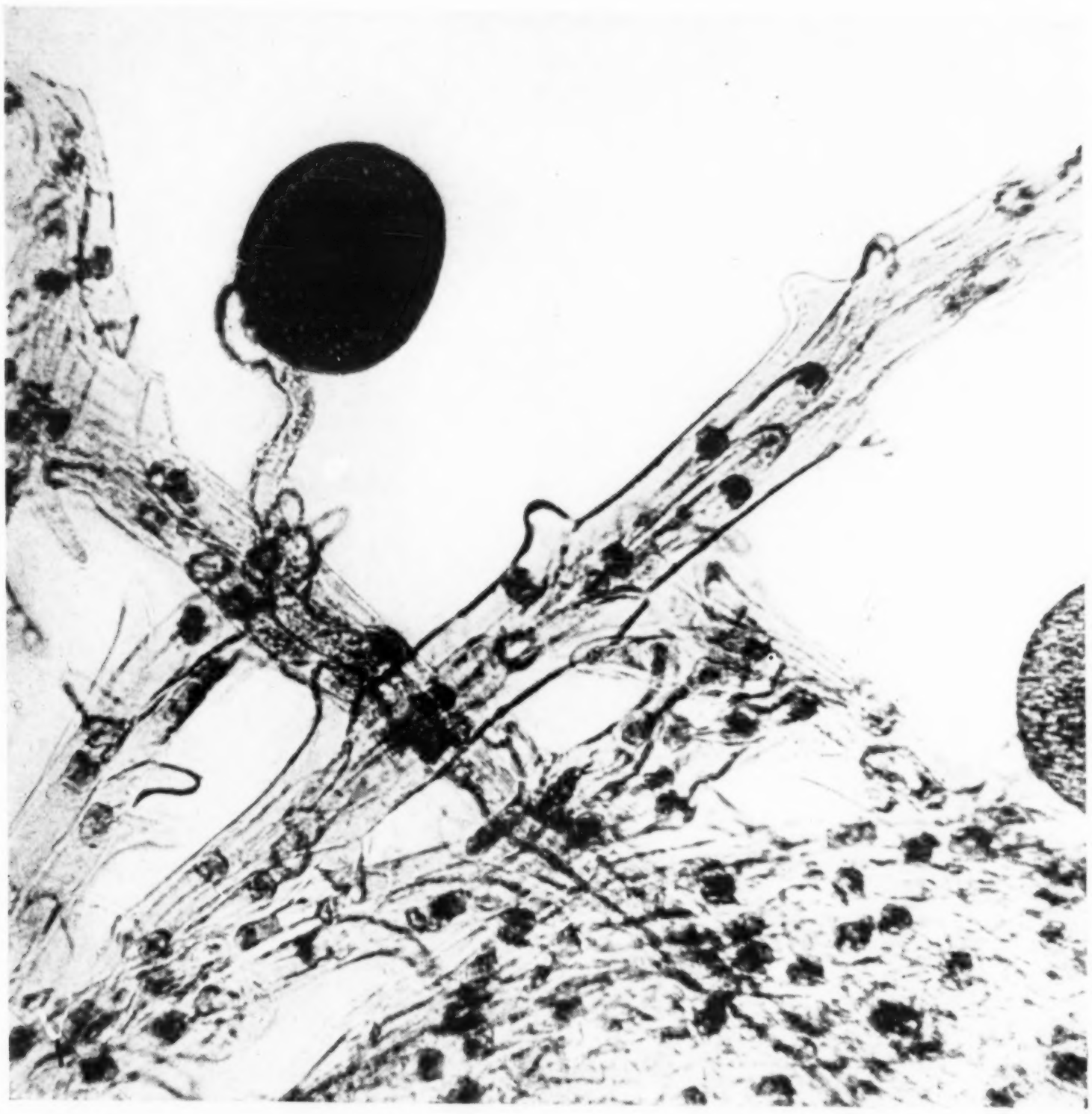
Portion of the style, highly enlarged. Numerous pollen grains have already fallen on it and can be seen adhering to it; in several cases they can be seen putting forth pollen tubes. These penetrate the stigma and grow down into the ovary; one of them finally comes in contact with the ovule, and fertilization ensues. (Fig. 16.)

qualitative differences, but by the quantitative factor—namely, the average yield of the progeny of each individual selection. This principle gives a far more satisfactory basis for work than the judging of a plant by its mere external characteristics, more especially when the end sought is an increase in prolificacy of a given variety rather than an improvement in some specific quality, such as milling excellence or rust resistance. It is therefore of great practical importance for those who are desirous of effecting improvements in prolificacy of our standard varieties of wheat.

Of course, in attempting an improvement in a given strain of wheat by any of the methods described above, care must be taken to avoid choosing those plants which excel their neighbors through merely accidentally favorable circumstances.

Irregular distributions of manure, variations in quality of the soil, and irregular seeding obviously lead to irregularities in the appearance of the individual plants, and considerable judgment is required on the part of the operator to decide whether the outstanding plants in a given crop really excel on account of individual excellencies or because they have been specially and accidentally favored in the struggle for existence.

The second method of effecting specific improvements in plants is by means of cross-breeding or hybridization.



HOW FERTILIZATION IS ACCOMPLISHED

This pollen grain has fallen on the stigma and put forth a slender tube which will grow down one of the branches of the stigma to the style, through which it will continue to grow until it reaches the ovule. Here, if favored by chance, it will come in contact with the minute ovule or egg cell. The nucleus of the pollen grain (the sperm cell), which has been gradually slipping down the tube, will then enter the ovule, unite with the nucleus of the ovule, and set in motion the machinery of cell division which will finally result in the development of a grain of wheat. (Fig. 17).

In effecting improvements by cross-breeding the mode of procedure is to cross two varieties of wheat possessing divergent and complementary characteristics, and selecting from the widely varying progeny those particular individuals which possess in the highest degree the specific qualities which we are seeking.

In order to apply such a method effectually it is necessary to have a clear conception of the goal towards which improvement is to be wrought, a knowledge of the unit characters of the different varieties, and of the laws governing the inheritance of these unit characters.

The act of crossing, and the actual production of merely new varieties is simplicity itself—the fixing and production of *valuable* varieties is extremely difficult.

Before discussing the method of crossing wheats, let us consider briefly the structure of a flower of wheat. The "head" or "ear" of wheat is known in botanical language as a spike, and consists of a flattened stem or rachis bearing alternately a series of structures known as "spikelets." Each "spikelet" or "chest" consists of several flowers. Usually each spikelet of most varieties has three to five flowers, from each of

which a grain of wheat may develop. The flower itself consists of two parts—

(*a*) the protective parts, consisting of glumes and pales.

(*b*) the essential parts—the stamens and pistil—*i. e.*, male and female organs. (Fig. 1.)

We are concerned here especially with the essential organs. The stamens (St.) are three in number, and represent the male organs. Each stamen consists of a slender stalk—the filament, bearing at its summit the anther or pollen sacs, which in the case of the wheat plant consists of four longitudinal chambers containing large numbers of minute pollen grains (sperm cells).

The female portion of the flower—the pistil—consists of the ovary with a minute ovule (or egg cell). The upper part of the ovary bifurcates and forms two long, slender, feathery structures—the styles. (Fig. 14.)

The pollen grain falls on the stigma of the flower and "germinates," sending a slender tube through the style until it reaches the ovule when the pollen nucleus slips down the tube to join the ovule nucleus, and fusion and fertilization take place.

How the crossing is done.—In the case of the wheat plant the flowers are normally self-fertilized. Natural cross fertilization is very rare. Moreover the flowers are hermaphrodite, *i. e.*, male and female elements are borne on the same flower. The wheat plant is said to be in "flower" when the anthers begin to extrude from the glumes. With wheat, however, fertilization takes place before "flowering." In order to cross one variety with another it is necessary that the pollen of one variety should be dusted on the ripe stigma or female part of the second variety. The plant from which the pollen is taken is generally described as the male parent, whilst the plant on which the crossing is done is referred to as the female parent. I find the following method gives satisfaction. A well developed "ear" of the "female parent" is chosen and prepared in the following manner:—

The basal spikelets amounting to approximately one-third of the ear are stripped off, and the top third of the head removed with a pair of scissors. Four or five spikelets are thus left on each side of the center of the ear. These spikelets invariably contain three to five flowers. All flowers save the outside pair are removed with a pair of forceps. Thus the ear is reduced to 12 to 20 flowers (Fig. 18). It is now necessary to "castrate" the flowers by removing the three anthers from each. The point of the forceps is gently inserted between the upper margins of the inner and outer pales, and, by releasing the pressure on the forceps the flower is gently forced open, exposing the three anthers and the feathery stigma. With a little practice these anthers may be removed unbroken with one stroke of the forceps. It is, of course, necessary to prepare the ear in this fashion before any of the anthers have shed their pollen grains. The best stage at which to carry out the operation is when the anthers are just approaching maturity and turning yellow in color. Having castrated the whole of the flowers by the removal of all traces of the anthers, the ears may be wrapped in cotton wool until the stigmas of the flower become "receptive" or ready to receive the pollen. The cotton wool may then be removed, and ripe anthers of the particular variety desired as the male parent should then be secured. The anthers should be quite "ripe," *i. e.*, bright yellow in color, and just ready to burst. The anthers are seized with a fine pair of forceps, broken in halves, and the contents gently shaken or dusted over the feathery style of the female ear. Each flower is treated in succession in this way, and frequently, when the pollen is not in good condition, some of the anthers may be broken and left inside the protective glumes of the flower.

Instead of castrating and pollinating flowers on different days it is generally more convenient to remove the anthers and cross-pollinate the stigmas at the one operation. It is necessary in such cases that the stigma and anthers should be fairly "ripe," and care should be taken that self-fertilization does not occur. Any flowers in which the anthers have already liberated pollen should be suppressed.

After the crossing is finished the ear is wrapped up in cotton wool, or surrounded with a light paraffined paper bag to prevent the possible entry of foreign pollen. The ear is then labelled with the names of the male and female parents, date of cross, etc., and supported by a stake. A fortnight later the protective covering may be removed, and the ear allowed to ripen.

EFFECTS OF CROSSING.

It is interesting to note, in passing, the general effect of crossing two different varieties of wheat:—

(*a*) *Crossing Increases Vigor of Progeny.*—Darwin made an exhaustive comparative study of the effects of self-fertilization and cross-fertilization in plants. He has summed up his researches in the generalization that "Nature abhors perpetual self-fertiliza-

READY FOR CROSSING

At left, a head of wheat before treatment. At right, same head prepared for cross-pollination. (Fig. 18.)

tion." He showed that crossing within the limits of the species resulted in the production of a very vigorous offspring, while self-fertilization tends to weaken the offspring, and that flowers as a general rule are constructed in such a manner as to favor cross-fertilization. In the case of wheat, however, it must be remembered that the flowers are normally self-fertilized, and that cross-fertilization under natural conditions is extremely rare. There can be no doubt that in the cross-breeding of wheat the immediate effect is a general marked increase in the vigor of the cross. This increased vigor finds its expression generally in increased height, increased stooling capacity and size of head in the cross-bred progeny. Whether this increased vigor is, however, a permanent characteristic or a mere temporary improvement has not been definitely established in the case of wheat.

(*b*) *Crossing "breaks the type"* and induces variation. Cross-breeding is one of the most powerful methods of inducing variations in a given type. There is no variety of wheat grown at the present time but what has some serious defect. It frequently happens that given varieties are specially well dowered with certain desirable qualities, but are sadly deficient in other necessary qualities. It is now possible by systematic cross-breeding to combine the desirable qualities of two or more individual types in one variety, and eliminate any undesirable qualities. Farrer relied almost entirely on this method for the production of his new varieties. Federation, the most popular and prolific wheat in general cultivation in Australia at the present time; Cedar, Bobs, and Comeback, wheats of the highest milling excellence; Florence and Genoa, varieties which are smut resistant; and Bunyip, Thew, Bayah, Firbank, Warren, Jonathan, and a host of others have been produced by Farrer by means of cross-breeding. It is by means of the variations induced by crossing that improvement on existing types becomes possible.

Obviously, the wider the initial differences between the two plants the more widely will the progeny vary.

Some idea of the difficulties which beset the early workers on this field of inquiry may be gathered from the history of a typical cross-bred seed. Suppose, for example, the variety known as Clubhead, which is a stiff-strawed, beardless, dark-chaffed variety with a dense compact head, be crossed with Yandilla King, which has a long, white, somewhat open head with firm closing glumes. The plants of the first generation will invariably be slightly clubby in character with reddish-brown chaff. Now from this single cross-bred plant a thousand seeds might be produced. If every one of these seeds be separately sown the next season an unending variety of plants will arise.

Every gradation and combination between the characteristics of the Clubhead on the one hand and the Yandilla King on the other appear to make themselves manifest in this generation. Indeed, characters appear in this generation which were latent in the originals, *e. g.*, many of the progeny will be found with beards. Apparently chaos is the result of this simple act of crossing. Further, if a few grains be selected from each of the thousand plants and again be sown separately, it will be found that in the third generation some of the plants breed true to type whilst others give still further complex variations. This apparently chaotic result arising from the growing of a single cross-bred seed puzzled and confounded the early hybridizers and investigators. If by cross-breeding plants possessing specific characteristics the progeny were found to obey no definite laws it follows that the improvement of plants by this method would be nothing more than a mere gamble.

Lindley, indeed, some fifty years ago, declared that the improvement of plants by cross-breeding was a game of chance with the odds in favor of the plant.

If, on the contrary, the laws of inheritance of specific characteristics could be formulated and definitely known it manifestly follows that the work of plant improvement would be reduced to scientific exactness.

Gregor Mendel, monk and abbot, of Brünn, in Austrian Silesia, was the first to unravel this tangle, and present to the world a clear and lucid exposition of the inheritance of specific characters in cross-breeding.

Mendel's work has been confirmed by many workers in widely different fields of investigation. Besides Correns, Tschermak, and De Vries, who were responsible for the rediscovery of Mendel's work, there have been confirmatory contributions by Darbishire on Mice, Hurst on Rabbits, Davenport on Poultry, Vilmorin, Nilsson-Ehle, Biffen, Spillman, and Howard on Wheat, Bateson, Saunders, and others on Lychnis, Atropa and Matthiola, and Toyama on Silkmoths, to name only a few.

MENDELISM IN WHEAT.

It is of great practical importance to know whether the laws of inheritance formulated by Mendel and developed by his successors may be applied in practice to the improvement of wheat. A considerable amount of data has accumulated during recent years on the inheritance of unit characters in wheat, and this tends to show that—

(1) The process of "fixing" new crosses, which formerly required considerable time and a vast amount of labor, may be greatly simplified.

(2) The wheat breeder can predict with a tolerable amount of certainty what combinations of unit characters may be associated and fixed in a new variety.

(3) The breeding of new varieties possessing certain specific attributes and desirable qualities may be accomplished with certainty.

The most prominent investigators in this field of work are Tschermak,[14] Spillman,[15] Biffen,[16] Nilsson-Ehle,[17] and Howard.[18] The first essential, of course,

[14] *Tschermak*—Die Züchtung der landw. Kulturpflanzen Bd. IV., 1907.
[15] *Spillman*—Science XVI, 1902.
[16] *Biffen*—Journal of Agri. Science, 1905, 1907, 1908, 1909.
[17] *Nilsson-Ehle*—Kreuzungsuntersuchungen an Hafer und Weizen Lund, 1909–1911.
[18] *Howard*—Memoirs of the Imperial Dept. of Agric., India, Vol. IV, No. 8, Vol. V, No. 1.

is to determine what characteristics in wheat are dominant and what recessive. Tschermak after an exhaustive and critical study of the behavior of the various contrasted unit characters in wheat states that the following attributes are respectively dominant and recessive, in strict accordance with Mendel's law:—

WHEAT ALLELOMORPHS.

Dominant.	Recessive.
Hairy leaves.	Smooth leaves.
Solid stem.	Hollow stem.
Firm closing of glumes.	Loose closing of glumes.
Felted glumes.	Smooth glumes.
Black chaff.	White chaff.
Flinty grain.	Floury grain.
Winter form (late shooting).	Spring form (early shooting).
Lax ears.	Dense ears.

These have been confirmed in general by Biffen and Spillman, though in the case of bearded and beardless wheats the ratios are often very far from following Mendel's law, as Saunders,[19] Howard and others have pointed out.

Biffen has obtained similar results at Cambridge. In addition he has shown that the following characters behave as Mendelian units:—

Dominant.	Recessive.
Red Grain.	White Grain.
Hard translucent endosperm.	Soft opaque endosperm.
Susceptibility to yellow rust.	Immunity from yellow rust.

In the following characters there is no dominance of either character, and the progeny in the first generation are intermediate:—

Lax and dense ears.
Large and small glumes.
Long and short grains.
Early and late ripening.

In the second generation two of the intermediates occur to each pure character—D:2DR:R.

The determination of the mode of inheritance of these various unit characters is of the greatest practical importance, for it enables the breeder to predict with tolerable certainty the forms resulting from the mating of two plants whose qualities can be expressed in terms of one or more unit characters.

One of the most interesting of the researches carried out in the production of new varieties of wheat is that done by Biffen in the production of the apparently impossible combination in the one variety of prolificacy, resistance to yellow rust, and high strength.

The wheats grown in England are very low in strength, and this defect is reflected in the disparity in price at Mark Lane between the Home-grown wheat, and the strong foreign wheats like Manitoba No. 1. It was formerly thought that this low strength of the wheats grown in England was due to the peculiarities of the climate.

A trial of a large number of foreign varieties of high strength under Englsh conditions proved that while the greater majority deteriorated immediately, there were a few varieties which retained their strength perfectly under the new climatic conditions, and gave as good results in the bakehouse as when grown in their native lands. These varieties, however, were of little use to English farmers, for they lacked yielding power of both grain and straw. Biffen, therefore, crossed these varieties of high strength with the prolific English varieties with the object of obtaining suitable varieties of high strength. Strength is defined as to the capacity of the flour "to yield large well-piled loaves," and while it is not an easy matter to give in non-technical language the difference between strong and weak wheat, it may be said that in general strong wheats are characterized by hard, more or less transparent endosperm, whilst weak wheats are usually soft, starchy, and opaque. In a certain cross between Red Fife and Rough Chaff a statistical examination of the progeny revealed the fact that in the first generation all the plants possessed strong grain, and that in the second generation the strength and weakness behaved as Mendelian characters giving the following ratio:—Nine strong red, three strong white, three weak red, one weak white. Biffen showed that these characters of strength and weakness in wheats could be handled with the same definiteness as other Mendelian characters.

[19] Saunders, Inheritance of Awns in Wheat, Conference on Genetics, 1906, p. 370.

CROSS-POLLINATING WHEAT FLOWERS

In order to combine the desirable qualities of several strains in one, the breeder resorts to cross-pollination. To do this he removes part of the flowers from a head of wheat, as is shown in this photograph, and then removes the anthers or pollen sacs from all the remaining flowers. These, in which only female or pistillate organs remain, are known as the seed-bearing parent of the cross. Some other variety is selected as the male or pollen-bearing parent, and from flowers of such variety the anthers are cut out and burst over the flowers of the seed-bearer, their pollen falling on the stigmas of these flowers and causing cross-pollination by the method shown in the preceding photographs. After pollination has been made, the flowers are protected by a wrapper of cotton batting, in order to avoid the possibility of any subsequent pollination by wind or insects, which might seriously interfere with the breeder's plans by changing the heredity of the resulting seed. (Fig. 19.)

Similar results were obtained with the inheritance of yellow rust (*Puccinia glumarum*) which does great damage in England.

Crosses between varieties which were immune from yellow rust and Michigan Bronze, a variety inordinately prone to rust, gave a first generation crop of hybrids which were as badly affected with rust as Michigan Bronze itself. A statistical examination of the second generation plants gave 1,603 diseased plants and 523 immune, or a ratio of 3.07:1. Apparently, therefore, immunity and susceptibility to yellow rust behave like Mendelian characters.

It is not known to what the resistance of the rust is due. Working with Professor Biffen, Miss Marryat found that the rust hyphæ are checked after entering the stomata of the resistant plants. Bateson points out that if the resistance to yellow rust is due to the presence of some anti-toxin the dominance of susceptibility must be taken to indicate that the formation of the anti-toxin is prevented by the presence of a factor in the dominant form, a conclusion which may lead to definite progress in the physiology of disease resistance. This yellow rust (*Puccinia glumarum*) is not the rust so frequently found in Australia wheat fields. The species of rust which causes so much damage here is *Puccinia graminis*.[20]

Many of the unit characters so far studied in wheat have been those which are of relatively little value to the practical agriculturist. The color of the chaff, the character of the awns, the hairs on the glumes, etc., are of great interest from a scientific point of view, inasmuch as a systematic study of them will serve to throw much light on obscure problems of inheritance, but they are of infinitely less practical utility than such characteristics as prolificacy, drought resistance, and early maturity.

Unfortunately very little work has been done in regard to these important practical properties, and a systematic analysis of the factors on which these qualities depend, and of their mode of inheritance, is urgently required. We do know that the prolificacy of any variety of wheat is a complex of many factors. The yield depends on the climate; the chemical, physical, and biological condition of the soil; and on the qualities inherent in the variety.

Of the qualities inherent in the variety the most important are the capacity to develop a vigorous root system, and to stool thoroughly. Other factors are the average length and density of the ears—the number of fertile florets carried to each spikelet, and the average size of the grain. We do not know, however, as yet whether high yielding and low yielding capacity behave as Mendelian characters and segregate as such in the second generation.

CONCLUSION.

During the past few years efforts have been made by ardent enthusiasts to extend Mendel's law to all branches of animal breeding, and to make it fit in with our present day knowledge. Interesting results have certainly been obtained in the cross-breeding of poultry, mice, rabbits, and polled cattle, but a considerable amount of ingenuity will be required to explain many of the discrepant and discordant results obtained with sheep and pigeons, etc.

Whatever the future may have in store in the practical application of Mendel's work to animal breeding, there can be no doubt that the present day breeder can, with the aid of the key given by Mendel, proceed on his work of plant improvement without leaving much to chance. The best results will follow when the individual plant is regarded as being built up of a number of unit characters, each of which follows a definite scheme of inheritance. The terms dominance and recessiveness should be applied, not to individual plants, but to each of the unit characters which collectively make up the organism. The schemes of inheritance of many of the unit characters have been worked out in detail, but there are qualities of great practical importance which require further investigation. We require to know exactly what are the

[20] *Puccinia graminis* is the late stem-rust of the United States. The early orange leaf-rust of the U. S. is *P. rubigo-vera*.—The Editor.

various factors on which these important qualities depend, whether they conform to the Mendelian scheme of inheritance, and whether they are transmitted independently of other factors, or in association, and, if so, how close the association is.

The aim of the wheat-breeder is always an improvement in type, the production of varieties possessing the maximum of desirable qualities, and the minimum of undesirable attributes. If he knows that the desirable qualities he is seeking are in two or more strains it is his task to unite the desirable qualities in the one strain. His most important problem is to determine by analysis and experiment the factors on which the desirable characteristics depend. But as soon as these factors have been determined, and their mode of inheritance investigated, they can be brought under control and associated together at the breeder's will.

SUMMARY.

1. The enriching and improving of the soil has been the dominant note in our system of wheat farming during the past generation.

2. There is reason to believe that as much attention might profitably be given to the improvement of the plant as there has hitherto been given to the improvement in its environment.

3. The primary aim of wheat improvement is the production of prolific varieties. Other important considerations are milling quality of grain, drought resistance, and rust resistance.

4. Extraordinary activity is being displayed throughout the world in wheat improvement.

5. Varieties may be improved by selection and cross-breeding.

6. Every care should be taken by farmers to get (*a*) the right variety of wheat, (*b*) well-developed seed, (*c*) seed from the most vigorous plants.

7. The common beet containing 6 to 7 per cent. of sugar has been developed into the sugar beet containing 20 to 25 per cent. of sugar by systematic selection.

8. Selection is based on variation.

9. Most variations are small, and diverge only slightly from the mean of the species. Others are large, and vary widely from the mean (mutations).

10. There are two general methods of selection: (*a*) mass selection, (*b*) individual selection.

11. "Mass selection" has been effectively applied by farmers to the improvement of their crops. It must be continuous and uninterrupted.

12. "Individual selection" is more complicated, and requires elaborate records and trials for its successful application.

13. The introduction and acclimatization of certain foreign varieties is likely to lead to valuable direct and indirect results.

14. New varieties may also be obtained by cross-breeding.

15. The immediate effects of cross-breeding in wheats are (1) increase in vigor of progeny, (2) a "breaking of type."

16. Mendel showed that the variations induced by crossing follow definite laws.

17. Mendel's results have been generally confirmed by workers in widely different fields of inquiry.

18. The mode of inheritance of many unit characters in wheat has been worked out in detail.

19. The mode of inheritance of other characteristics in wheat of great practical importance has not yet been worked out.

20. The well informed wheat improver may enter on his task of wheat improvement without leaving much to chance.

EUGENIC LEGISLATION

Much of it Worse than Useless Because Based on Lamarckian Theories—Other Statutes Sound Biologically but Wrong Sociologically—Need for Caution but Possibility of Positive Achievements.

A Review.

STUDENTS of human heredity will view with satisfaction the appearance of bulletin No. 82 of the University of Washington,[1] which gives in 87 pages a summary of the laws of the several United States governing: I.—Marriage and divorce of the feebleminded, the epileptic and the insane; II.—Asexualization; III.—Institutional commitment and discharge of the feebleminded and the epileptic. After giving summaries of all the laws in question, in a clear and concise form, the authors terminate their work with four pages of temperate discussion of the entire subject of legislation intended to prevent the breeding of a degenerate race in the United States, pointing out that some of this legislation is so out of date, from a biological point of view, that it is worse than useless.

"A half century ago," they remark (p. 82), "educators still hoped by intensive education so to improve the mental condition of the feebleminded as to make advisable their leaving the institution and assuming some, at least, of the duties of normal people. If this policy of the educators were to benefit society, it must have presupposed that acquired traits are, in the full meaning of the term, inherited. And this no one at that time doubted.

"Today we know that nearly all forms of mental deficiency are incurable, and most biologists believe that, in the full meaning of the term, acquired characters are not inherited. Legislatures, however, have other tasks than the study of modern biological theory, so that we see the opinions of Lamarck and of Seguin almost unchanged in many of the state laws.

"For instance, a number of institutions for the feebleminded are intended only for those who 'may be benefited by the instruction.' The Illinois application blank indicates this. The governor of New Jersey is empowered to remove any child who is not benefiting by the instruction given. Delaware, which sends its feebleminded to the institutions of other states, orders its patients discharged when they may no longer receive benefit from training. In Kentucky the superintendent of the institution is supposed to return to the counties all patients, further attempts to educate whom will not prove beneficial to the state. Also, no child may be kept in the institution after arriving at such age and mental condition that he will be able to provide for himself.

EDUCATION NOT A REMEDY.

"Regulations such as these are not often put to any greater use than necessary, but they still reflect the opinion of a few decades ago, that the superficially educated defective makes better material for parenthood than the uneducated defective. To discharge, unsterilized, the defective child, after having taught him habits of neatness and a few tricks that make his mental deficiency less noticeable, is worse than never to have put him in an institution. The same criticism applies, of course, to the special classes in the public schools.

"Among the marriage and divorce laws there is more Lamarckian biology. Kansas forbids the marriage (unless the wife is over 45 years of age) of children

[1]The Bulletin of the Univ. of Washington no. 82 (Seattle, Wash., May, 1914), "A Summary of the Laws of the Several States, etc.," by Stevenson Smith, Madge W. Wilkinson and Lovisa C. Wagoner of the Bailey and Babette Gatzert Foundation for Child Welfare.

born after a parent was insane. Michigan and New Jersey demand the 'cure' of defectives before marriage. Divorce is granted in Utah on the ground of insanity only when the condition is incurable.

"The Michigan asexualization law provides for sterilization when 'there is no probability that the condition of such person so examined will improve to such an extent as to render procreation by such person advisable.' A similar provision is found in the North Dakota law."

The authors go on to point out that some sterilization measures which are sound biologically may be quite wrong from a sociological point of view. In such a case, legislation must proceed very slowly. Finally they discuss briefly the whole question of whether laws to prevent bad breeding are feasible.

"A frequent charge made against eugenic legislation is that it is unwise, that it is conceived in the isolation of the schools and will never bear the test of common use. Our attention is called to the many Utopias which have come to pass only in the minds of philosophers, and to the failure of most 'ideal' communities due to their disregard of common-sense premises.

"Another objection to such laws is raised by the 'all for love and the world well lost' school. In their opinion, even granted that by the exercise of the police power it were possible to realize this academic dream, the Eugenic State must necessarily be a cold blooded breeding station where romance is the price paid for a better race.

"Then there are theological objections. These apply especially to asexualization. It is the opinion of some people that although to operate on a man for his own good is justifiable, to operate on him for the good of society is to tamper with the plans of Providence. One also hears it said by people who are not avowedly actuated by theological considerations that such operations are 'unnatural.'

"Lastly, the position is taken that eugenic laws are impracticable, that society will not tolerate them. To be sure, society has tolerated sex taboos and legal penalties much more onerous, but long standing has made them seem 'natural.'

OBJECTIONS EASILY ANSWERED.

"The objections, then, to the legislative attempt to apply the known facts of biology to the betterment of human stock are (1) that the laws themselves would not accomplish what their authors predict, or (2) that the cost of reform is too great, or (3) that the laws are impious, or (4) that society is incorrigible and the laws cannot be enforced. In addition to these, Mr. G. B. Shaw has said that we do not know what type of human being we wish to develop, but as the opinion of society has in the past been a great factor in determining the survival of individuals, this objection holds only within certain limits. We are rather confident that there are certain characteristics we might wisely eliminate.

"To take issue with these antagonistic criticisms of eugenic legislation is hardly the purpose of this publication, though a few of the more obvious rejoinders may be noted. The inheritance under certain conditions of mental deficiency is undisputed. Also the fact that mental defectives are undesirable seems evident. With such a backing for the project, the further social control of the defective deserves being tried out. Ultimately every social measure must survive or be eliminated according to the results of its practical application. To call legislation experimental is to praise it. If less legislation were regarded as final and more were measured by its results, we might have a better working code.

"The second objection is due to ignorance of the history of sex taboo. When it is realized that the present limitation of our individual liberty in the matter of marriage is tacitly accepted by nearly everyone, and that certainly in the past much of this limitation was ridiculous, the objection to further limitation of a desirable sort falls to the ground, especially as in the change many of the present useless taboos will be eliminated. The taboo against incest, that of the Jews against all exogamy and our own

against mating with certain alien races are not irksome to the average man. They rather add to the romance of marriage. An aristocratic pride of race is not antagonistic to a man's choice of a mate, but rather determines it and adds ultimately to his satisfaction. Certainly marriages are happiest when a wise taboo is respected.

"It seems hardly necessary to meet the theological objections to progressive legislation along biological lines, as some theologians are among the ablest supporters of eugenic laws, and those who are not would not agree with the premises of eugenics. A bishop, recently addressing a university audience, condemned the eugenic movement, saying that the selection of the more fit only limited the field of religion, as it is the unfortunate who need religion most. Fortunately this is not a prevalent view in any church.

NEED FOR PUBLIC SENTIMENT.

"In supposing that eugenic laws cannot be enforced, critics doubtless have in mind what they regard as analogous cases of laws which were enacted and became dead letters because the public did not feel their importance. Anti-tipping laws are examples of this, and the public certainly must demand such a law in advance of its enactment if it is not to die on their hands. Much eugenic legislation is, however, not prohibitory in character, but is permissive of certain powers on the part of the courts or of commissions appointed for a definite purpose. It is this sort of legislation that must necessarily work best, as it is not subject to violation and will continue to be used as long as even a few people are intelligently interested in it.

"Whatever may be said against such laws as are presented in this pamphlet, and they are rightly subject to much criticism, it is evident that something must be done to diminish the number of mental defectives in our population. War among primitive people, poverty, disease, and capital punishment did a fairly thorough if not a very beautiful piece of work before we began to civilize them away. Some substitute has to be found for natural selection. Procreation of the undesirable must be prevented by means which are least cruel and least wasteful. These laws already in force in the several states indicate the growth of this opinion."

Crosses With Zebu Cattle

Crosses between zebu and native Italian cattle, made at the zoötechnical institute of Perugia, are discussed by Director Carlo Pucci in L'Agricoltura Coloniale, No. 10, 1914. The results convince him that (1) in all the first generation progeny the zebu skeleton, dewlap, ear and musculature seem to be dominant; (2) the skin color and size of horns of the zebu seem to be recessive; (3) in general, all the progeny show great activity and endurance; (4) they have a very valuable predisposition to lay on weight; (5) they have a very high resistance to the foot and mouth disease.

Pollination of Cherry Trees

That cherry trees frequently prove shy bearers because of inadequate pollination has been demonstrated at the state agricultural experiment station in Oregon. It is found that some of the leading commercial varieties are practically self-sterile, while others are inter-sterile; that is, some varieties are much better pollenizers than others for orchard planting. Sometimes pollination works well in one direction, while the reciprocal cross produces very little fruit. It thus becomes necessary for cherry growers, particularly in regions where only a few varieties are produced, to study each individual variety and find out its needs in pollination, if they would avoid disaster. Inter-sterility among varieties is found not to be correlated to closeness of relationship.